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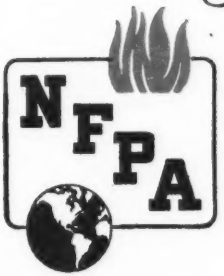
NATIONAL FIRE PROTECTION ASSOCIATION

Quarterly



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G•J•S E-430-1 NFPA October, 1951

Part I

Volume 45 October 1951 Number 2

Quarterly

The Standard Technical Journal of Fire Protection for More Than Forty Years

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of the

National Fire Protection Association

International

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The National Fire Protection Association is a non-profit technical and educational organization devoted to the reduction of loss of life and property by fire with more than 13,000 members. The *Quarterly* is one of the publications regularly provided to members. Other membership publications include a monthly *Fire News, Advance Reports* and *Proceedings* of the Annual Meetings, a *Year Book*, and many leaflets, pamphlets and posters issued throughout the year on fire prevention and control.

Technical committees of the Association develop means to safeguard life and property through the publication of standards covering all phases of fire prevention and protection. Your membership in the Association (annual dues $12.50) affords an opportunity to keep abreast of these developments and, by being a member, you help support this humanitarian activity. Popular educational literature on fire safety is constantly being produced by the NFPA for distribution through its members to the general public.

All members of the Association and the public are invited to NFPA meetings. The following dates are now on the Calendar:

NFPA Calendar

1951	
Oct. 24-25	Regional Meeting, Portland, Ore.
Oct. 29-30	Regional Meeting, Los Angeles, Calif.
1952	
June 9-13	Annual Meeting, Hotel Statler, N. Y.
Oct. 27-29	Regional Meeting, Cleveland, O.
Dec. 1-3	Regional Meeting, Houston, Tex.
1953	
May 11-15	Annual meeting, Palmer House, Chicago.

QUARTERLY
of the
NATIONAL FIRE PROTECTION ASSOCIATION

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Volume 45 | October 1951 | Number 2

Table of Contents

Part I

Gas Explosions in Brighton, N. Y. ..... Frontispiece
Afternoon in Brighton (Gas Explosions)
Allen L. Cobb 85
Gas Pipeline Break, Jefferson, Pa. 92
Allison Jet Engine Test Cell Explosion 95
Obstruction in Sprinkler Piping 102
Kentucky Inspection Bureau
Burning Characteristics of Building Materials
A. J. Steiner, Underwriters' Laboratories 103
Halogenated Extinguishing Agents
Drs. R. C. Downing and *B. J. Eiseman, Jr.*
E. I. duPont de Nemours & Company 110
J. E. Malcolm
Engineer Development and Research Laboratories, U.S. Army 119
Arson Investigation in Selected U. S. Cities
Kuan-Lou Lee, University of Southern California 132
Transporting Hazardous Materials
Roy C. Petersen, Port of New York Authority 144
New Test Apparatus for Dust Explosions
Paul E. Cotton, Factory Mutual Laboratories 157
New Light on Self-Ignition
Nolan D. Mitchell, National Bureau of Standards 165
Fires and Fire Losses Classified, 1950 173
Index to Advertisers 180

Part II

NFPA Officers and Committees (Roster) ..... Bound Separately

Accounts of fires appearing in the Quarterly are copies of or extracts from reports forwarded to the Association except where otherwise indicated. The Association, as a body, is not responsible for the statements or opinions of any of its members. This publication is indexed by Engineering Index, Inc.

Rochester Democrat and Chronicle—Gannett News Helicopter

Three houses on Antlers Drive in Brighton, N. Y., which sustained total losses as the result of a series of gas explosions in the suburban town on Sept. 21, 1951. Three persons died and a total of about 30 homes were damaged or destroyed after an explosion in an underground vault wrecked pressure regulating valves, allowing natural gas under high pressure to pass through the low pressure domestic service mains and into the dwellings. **(See story starting on page 85 of this "Quarterly.")**

on Sept. 21, 1951. Three persons died and a total of 300 under high pressure to pass through the low pressure domestic service mains and into wrecked pressure regulating valves, allowing natural gas under high pressure to pass through the low pressure domestic service mains and into the dwellings. (See story starting on page 85 of this "Quarterly.")

The Quarterly

Vol. 45 October 1951 No. 2

Afternoon in Brighton

By Allen L. Cobb*

Brighton, New York, is one of those fresh painted, well scrubbed, tree shaded and gardened suburbs that make it an ideal residential community for one of our larger cities. It is one of those communities which comes within the general description of "middle class"; a community of home owners who are largely professional people — in this case, doctors, lawyers, and the small business men of Rochester.

Brighton on Friday afternoon, September 21, 1951, was hardly the spot where you would expect an accident or disaster of any kind. It has almost no business buildings and certainly no structures housing any major degree of hazard. Lots are large. The houses spaced well apart. Dwelling construction ranges from good to better, with an appreciable number of really attractive homes. On this Friday afternoon, the skies were clear. There were no appreciable winds. Most of Brighton's children were at school, but some were home, as parochial schools were closed for a teachers' meeting.

In the home of William Maas, Jr., eight-year-old Mary Ann and five-year-old William were resting after lunch in the care of Mrs. Verda Durham, the housekeeper. Outside, mowing the lawn was sixteen-year-old Hugh Crilley of Allentown, Pennsylvania, who was in Brighton visiting his friend, Tom Kuhns. Tom usually mowed the lawn for the Maas family, but he had something else to do that afternoon.

That was the scene at the Maas home when Mrs. Durham called her employer to tell him of some trouble she was having with the pilot on the gas stove.

That was the last contact William Maas had with his family, for soon after Mrs. Durham hung up the phone, there was a terrific explosion which blew the house to the four corners of its spacious lot.

Firemen found Mrs. Durham alive, but badly injured, in the debris that filled the cellar. Mary Ann and William died in the explosion and fire. Hugh Crilley, on the lawn outside, received first and second degree burns on hands, arms, and face and other injuries to his left arm.

Elsewhere about the area, other houses exploded (eleven in all). In addition, some 20 dwellings caught fire from abnormal internal gas flames or from exposure fires. In a very few minutes, indeed, the peaceful town of Brighton was faced with a major emergency.

*Mr. Cobb, Safety Supervisor of the Eastman Kodak Co., Kodak Park Works, Rochester, kindly volunteered to prepare this article for the *Quarterly*, since he was promptly on the scene of this tragic accident.

Rochester Democrat and Chronicle—Gannett News Helicopter

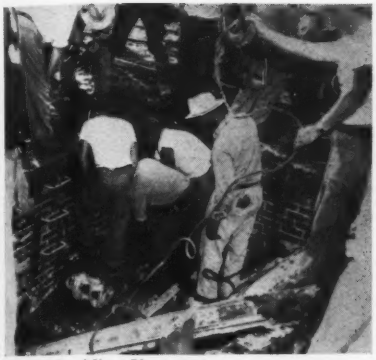
The two children of Mr. William Maas, Jr., died in their home soon after the housekeeper called her employer advising of trouble with the pilot on the gas stove. The housekeeper was rescued by firemen and is recovering.

Origin Underground

The origin of the trouble was at an underground vault built in two sections, each about eight feet square, underneath a sidewalk in front of the Chateau Restaurant in the central part of the town, known as "Twelve Corners." Directly across Monroe Avenue, the principal highway through Brighton, is a large Howard Johnson Restaurant. On the other side of the square are Brighton's grade and high schools. In this neighborhood, also, is the Brighton Fire Department's No. 3 Station.

Located in these underground vaults were two sets of gas regulators in parallel. One set consisted of four-inch high and low pressure regulators on a four-inch main, the other, a similar set of six-inch regulators on a six-inch main. The pressure reduction was, first stage, from 30 lbs. to 5 lbs. and, second stage, from 5 lbs. to six-inches water pressure. High pressure regulators and dust filters were in one vault; low pressure regulators in the other. There were numerous openings between the two vaults. Valves were arranged to permit the use of either set of regulators, and, at the time, the four-inch regulator set was in service. The vault was roofed with railroad rails covered with concrete.

On this Friday afternoon, workmen of the C. P. Ward Construction Company were engaged in sidewalk work just over this area. Work had been finished for the



International News Photo

One of the two underground vaults which housed the pressure regulators. The initial explosion occurred here, damaging both regulators and allowing gas under high pressure to enter the domestic lines.

day and they were moving their equipment away just at the moment a terrific explosion occurred in the vault, blowing off the concrete roof. Fire followed the blast.

Initial Explosion in Vault

The exact cause of this explosion is not known and may never be known. It seems evident that a natural gas leak occurred in or penetrated into this vault but, because of explosion damage, the source and cause of this leakage and the source of ignition are not definitely known.* It is believed, however, that this initial explosion in itself would not have caused appreciable damage in the community. However, heavy pieces of the vault roof, falling back into the vault, struck and seriously damaged both the high and low pressure regulators so that full gas pressure of approximately thirty pounds-per-square-inch entered the low pressure piping.

*While the exact source of ignition may never be known, a construction employee stated that he placed a lighted red lantern on a barricade at the edge of the sidewalk before leaving, and one witness has stated that fire flashed from the lantern to a manhole cover.

The gas piping in this area of the community was a low pressure installation without regulators at individual houses. The high pressure gas entering these systems caused burners to shoot up, and, in many cases, the tin case gas meters were ruptured, allowing free escape of the gas into basements.

While the next half hour must have been of real terror and confusion to the residents, many housewives and most of the few men at home or at work in the neighborhood went from house to house closing gas valves. As the news spread, police, civil defense workers and men of the community arrived and continued entering houses already filled with gas at very considerable risk to themselves.

Public Agencies Responded

Announcements were quickly broadcast over the major radio stations advising all householders to open windows and get out-of-doors. Police prowl cars went through streets with public address system speakers repeating the message. Credit for this activity belongs to the utility company, who requested both agencies to carry these emergency messages.

Gas Company crews responded quickly and started to locate and close the valves necessary to isolate the area. While doing this, other gas crews turned water from fire streams into the gas drip connections in the vault to seal off the line and reduce the pressure.

Meanwhile all available employees of the Rochester Gas and Electric Corporation, electric as well as gas, were rushed into the area and went from house to house shutting gas cocks.

Principal Harris of the High School, walking through the basement, detected escaping gas, called the maintenance man and went to his office sounding the high school fire alarm. He then called the grade school and this building was likewise evacuated. The maintenance man succeeded in shutting off gas in both schools.

Rochester Democrat and Chronicle—Gannett News Helicopter

The scattered fires in the peaceful residential town brought county-wide fire services to the scene. The mutual aid plan plus the initiative and courage of many men and women kept loss of life and property to a minimum. Eleven houses were totally destroyed by internal explosions, two by internal fires (not preceded by an explosion) and about 18 others were damaged.

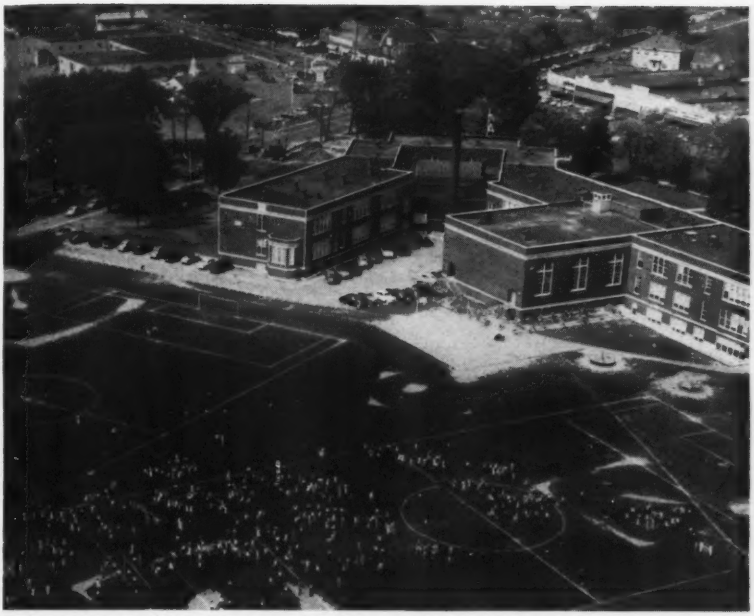
School pupils evacuated the schools but remained in their class groups in the recreational grounds until their parents could arrive to claim them. Residents of the area lined the streets or gathered in small groups but nowhere were there large crowds or confusion. Rochester's civil defense forces, hardly anticipating a real emergency call at this time, went into action and performed surprisingly well in view of their relatively small numbers and limited training.

The two members of Brighton No. 3 Station on duty (this is a volunteer department with paid drivers and a few full-time men) turned in a telephone alarm at the time of the vault explosion to Brighton Fire Headquarters and responded to the scene. The alarm was logged at 1:14 P.M. One man connected to a hydrant near the vault and started the pump, the other advancing to the vault with a water spray stream to protect exposures and permit close approach. (The gas was allowed to burn until the source of the leaking gas could be cut off.)

Police responded to the fire alarm and a police car made the first call for gas company assistance at 1:32 P.M., as recorded in the Brighton Police radio station. Gas and Electric trucks are radio equipped, and their response was prompt after the initial delay in notification.

County Mutual Aid Functioned

The elaborate and well-planned mutual aid system of the fire departments in the Monroe County area operated smoothly. As apparatus came into the emergency area, other pieces from outlying towns moved into city and town stations to stand



Rochester Democrat and Chronicle—Gannett News Helicopter

Grade school children are shown in the school playground after they were evacuated. (The high school is out of the picture to the left.) The vault where the initial explosion occurred is in front of the Chateau Restaurant (old building with tower) in background just to left of school chimney and across the street from the Howard Johnson restaurant.

by. Radio proved an invaluable help to units so equipped as telephone lines were quickly jammed. The situation, with some thirteen fires scattered over several square miles, necessitated prompt and accurate transmission of messages. One difficulty experienced, however, was the fact that Rochester Police and Fire Departments use the same frequency with the result that this system was badly overloaded because of the many units operating and transmitting urgent messages. County apparatus was not radio equipped although plans for such facilities are well advanced and the first units are scheduled for radio installations this October (1951).

In addition to fire departments, police units responded from the Sheriff's Office, the State Police, and all towns in the area. The American Red Cross responded promptly as did the Salvation Army and the Eastern Ambulance Service.

A radio-equipped truck of Kodak Park Works, Eastman Kodak Company, was sent in the area. Your reporter went to the scene in the Fire Chief's car from Kodak Park with Deputy Chief Karl Boeyink and found the radio in that car of considerable value. Help from the Kodak Park emergency service in the way of cranes and wrecking crews was offered but was not needed as there were very few pieces left in any of the exploded houses that could not be lifted by a few men.

How the Emergency Affected the People

Some of the points noted which may be of value in connection with our thinking in relationship to emergency service planning were as follows:

There was no panic or mass hysteria. The great majority of people acted with good judgment and remained calm throughout the entire emergency. There were, of course, isolated cases of over-excitement and at least one of real hysteria.

Auxiliary police and civil defense workers acted reasonably and intelligently and were not officious or arbitrary. Even after the area was put under tight control, persons who had legitimate business in the area were admitted quickly on identification and reasonable proof of their business.

In view of the seriousness of the accident the small (but pathetic) loss of life was remarkable. In addition to the two Maas children, a seventy-seven-year-old woman died from a heart attack. Low loss of life can be attributed to prompt spreading of information by radio and police public address prowl cars, the quick thinking and good judgment of many of the residents, the fortunate time the accident occurred and the good weather which found many residents out-of-doors.

Brighton on Saturday afternoon was rapidly getting back to normal. Electric power was restored to the area during Friday evening and residents returned to their homes. Some fifteen hundred gas meters were replaced during Saturday morning and afternoon. New main regulators were installed in the vault and ready for service, and work was proceeding rapidly in the house to house check of all gas services. Mains were dug up and blocked off so that gas could be admitted to the area in relatively small sections.

Rochester hotels offered their rooms to the homeless, and, of course, friends and neighbors did their share. A control center was set up on the lawn outside the Brighton Fire Department from which damage control and restoration of service was directed. Fire apparatus from Rochester and other communities remained lined up in the parking space of Johnson's Restaurant for the occasional calls made necessary by re-ignition of smoldering piles of debris.

Fire Services

Considerable credit for the organization and control of the emergency goes to the Rochester Fire Department under Chief Slattery. N.F.P.A. member Deputy Chief Ambrose Foos of the Rochester Fire Department is listed among the injured.

The Brighton Fire Department under Chief Albert DeHollander, badly overtaxed as it was, performed admirably. The call for mutual aid services was placed immediately, even before the full magnitude of the situation was known. The Brighton street layout is complex, largely designed to discourage through traffic on residential streets. One Brighton fireman was assigned to each arriving company to act as a guide. As the number increased, however, about all that could be done was to tell each arriving company to hunt out a fire and get busy. This they did with fine initiative and cooperation. About 30 companies were placed in operation during the emergency. Brighton fire fighters were overhauling, hours after the fire, and controlling small fires which reignited in debris.

The excellent facilities of the Brighton Fire Headquarters were made available for preliminary investigation meetings.

During the period of greatest demand, water pressures in the area were apparently low. There is no instance, however, of insufficient water for pumper suction. Spray was used wherever possible rather than solid streams to conserve water use.

Conclusions

Some conclusions in regard to gas utility practices appear to the writer to be in order. At this time, Oct. 1, 1951, the New York State Public Service inquiry has not been completed. More definite recommendations may be made following

Rochester Democrat and Chronicle

A ground view of the three houses shown in the frontispiece air photo as fire companies started to work. The house in the center was flattened by a gas explosion but fortunately no one was killed. About 30 fire companies operated during the emergency from Brighton, Rochester and many well equipped fire departments in the Monroe County environs.

this inquiry, but some of the things which appear worthy of consideration are as follows:*

1. A low-pressure area should not be fed from pressure regulators without definite overpressure protection on the low-pressure mains. This might well be done by installing two low-pressure regulators in series, one set at perhaps ten inches of water and the other at six inches. Failure of the lowest pressure regulator would result in ten-inch pressure on the system which would not be dangerous. Failure of the ten-inch regulator would not result in any overpressure. A relief valve should be connected between these two regulators and remote indicating pressure switches connected to both regulator outlets. These should be connected through telephone cables to the gas distribution headquarters and arranged to give an alarm for failure of either regulator.

2. A vent to a safe area from each underground regulator station.

3. A pressure regulator at each house service or, for low pressure systems, an automatic overpressure shut-off.

4. A safety valve arranged to close automatically in event of either over or under pressure may be desirable at each service.

5. The service cock is not desirable as a shut-off for use by the householder; something that can be operated by pushing a button and which can be restored only by a qualified persons appears desirable. The ordinary service cock requires a wrench and appreciable strength to operate. Service cock bodies can be broken by the effort required. An uninformed person might unintentionally turn the gas on again, not knowing that someone else has already turned it off.

6. Two-way radios should be limited to about 50 units for each assigned frequency and separate facilities and frequencies for each emergency service.

7. Fire department personnel should initiate calls for gas or electric crews immediately where their equipment is affected.

*The opinions expressed in this section are those of the author.

Observer Publishing Co.

This aerial view shows ruins of the parsonage (lower left) and four dwellings on Pine St., Jefferson, Pa., following a series of gas explosions on February 9, 1951. Another dwelling not visible was also destroyed. Natural gas leaking from a break in a 16-inch gas pipeline flowed into a storm sewer and entered the dwellings through storm sewer connections. The break occurred four feet beneath the frozen ground surface near the junction of the street and alley at left.

Gas Pipeline Break, Jefferson, Pa.*

On February 9, 1951 the village of Jefferson, Pennsylvania, located in one of the oldest natural gas fields in the United States, was rocked by a series of explosions which wrecked six homes, killed two people, injured six and caused $100,000 property damage.

The cause of the explosions was ignition of natural gas that had entered the various buildings through storm sewer connections. The source of the gas was a break in a wrinkle bend on a 16-inch gas line where it passed under a 24-inch terra cotta storm sewer at the junction of Pine Street and Gregg Alley. Relaid in Nov. 1946, the gas line was listed at 1600 lb. test, had welded joints and normally carried 200 lbs. pressure. At the point of the break, the gas pipe was four feet beneath the surface. Directly over the break a 10-inch steel lateral sewer pipe had been cut into the storm sewer providing an easy opening for the gas to enter the storm sewer system. The fact that the earth was frozen several inches deep prevented gas from escaping readily through the ground.

The Explosions

At about 12:05 P.M., Reverend Harland Hill in the Baptist Parsonage on Gregg Alley, near its junction with Pine Street, heard a noise like an explosion and thinking that there may have been some trouble with the furnace, he went to the basement but found the furnace in good shape. Returning to the first floor and looking out a window, he saw gas or the effects of it blowing from the storm sewer a short distance away, and immediately called the fire department. At this moment an explosion occurred in the Craft home 240 feet farther up Pine Street. While Rev. Hill was getting his family into the car to move them from this area, a second explosion occurred in the Morris home some 700 feet beyond the Craft dwelling.

In the meantime an experienced employee of the Equitable Gas Company, who was at the company warehouse located about 150 feet from Pine Street, heard gas escaping from the end of the sewer nearby. Realizing that the 16-inch gas line must have broken, he went toward Pine Street to warn the occupants of the homes but before he had gone far the explosion had occurred in the Craft home. Thinking that the explosion would warn more people than he could, he set out to close the valves which would take the pressure off the gas line. The nearest valves were at opposite ends of the town and about two miles apart. The second gate valve was closed about 20 minutes after the break was first discovered.

A member of the Jefferson Volunteer Fire Company on his way to lunch saw the first explosion. Very little fire was visible. He was told that there were two people missing but before much progress could be made in the wreckage two more explosions occurred in this house followed by intense fire that prevented further rescue attempts.

*Based on report submitted by Chief F. L. Hoover of the Waynesburg Volunteer Fire Department, Waynesburg, Pa.

on February 9, 1951. Another dwelling [illegible] a storm sewer and entered the dwellings through storm sewer connections. The break occurred four feet beneath the frozen ground surface near the junction of the street and alley at left.

Upon the arrival of the Jefferson Fire Company, the Baptist Parsonage adjacent to the church and the three houses on Pine Street between the church and the Craft dwelling sustained explosions. Gas was seeping out of the ground and roadway and burning in many places near the damaged houses. Gas burning at a catch basin produced a torch 10 to 12 feet high.

Fire Fighting

Volunteer fire companies from Carmichaels, Waynesburg, Rices Landing, East Bethlehem and Clarksville assisted the Jefferson Department. Carmichaels on their arrival stopped at the Morris house and did a good job in saving the adjacent Fatkin house after the exposed side wall had ignited. Waynesburg arrived with one truck at 12:45 P.M. and realizing that there would be a water shortage (Jefferson has no water system) called for another engine and an 1800-gallon tank truck. These two trucks arrived 20-30 minutes later and, with the help of Clarksville, firemen were able to bring the fire at the Craft home under control and remove the bodies of Mrs. Craft and a 21-months-old child.

In the meantime two volunteer companies ventilated the Baptist Church and extinguished small fires before extensive damage resulted. Other firemen went from house to house on Pine Street and asked occupants of undamaged buildings to ventilate and vacate their homes. To forestall any additional spread of fire, four fire companies laid a hose in relay to the nearest water supply, a creek three-quarters of a mile away, which was at approximately 150 feet less elevation. The stream produced through this line was ineffective but since the fires were by then extinguished and no more broke out, the additional protection was not needed.

Observer Publishing Co.

The cracked wrinkle bend in the 16-inch gas pipeline, the 24-inch terra cotta storm sewer and the 10-inch steel lateral storm sewer are shown in this picture. Gas from the crack entered the storm sewer and spread to several dwellings.

Allison Jet Engine Test Cell Explosion*

An explosion and ensuing fire in a jet engine test cell building killed eight employees of the Allison Division of General Motors Corp. at their Plant No. 3 in Speedway City, Indiana on July 12, 1951.

The building involved was a one story reinforced concrete structure with below grade areas throughout. The structure was heavily damaged and management estimates replacement costs at several million dollars. The explosion resulted from the vaporization and subsequent ignition of low flash point jet fuel (gasoline type) which was detected leaking from the fuel flow meter in one of the test cells shortly before the explosion occurred. The ignition source could not be definitely determined because of the extent of the damages, but it is believed that the vapor was actually ignited in another cell where an operating jet engine was under test.

All the test cells and control rooms in the building were vulnerable, if intercommunicating doors were open, to penetration by fuel vapors from a leak originating at almost any point within the structure. The test cells did not have basements, however, the cells extended below grade level and there was direct access from this below grade space to the basements of the control rooms and to a tunnel under a central corridor.

GENERAL: The test cells involved were the west block of 20 which constituted half a block of 40 cells. This 40-block test cell building adjoined, to the north, a manufacturing building. The other exposures to the 20-block cell group were a court (east), an automobile parking area (west) and a propane gas farm and a second parking area (south). The cells destroyed were designated No. 88 through No. 107 consecutively. The 20 test cells were located 10 on either side of a 10 ft. wide central corridor. (The even-numbered cells on one side of the corridor, odd-numbered on the opposite side.) The ground level floor of this corridor was a slab of 6-inch thick concrete, under which there was a tunnel (basement level). The cells were of the "U" type with vertical inlet and discharge stacks.

CONSTRUCTION: The cells were fire resistive with reinforced concrete walls. Test operations were at ground level on a structural steel platform using grating and plate flooring. The test cells extended below grade level and there was direct access between these areas, the tunnel under the corridor and the basements under the control rooms. Cells and control rooms were accessible at ground level from a central corridor and the cells were also accessible from the control rooms. Each pair of cells had a common operators room. Each control room had access to the outside, either to the open parking area (west row) or to small open court areas (east). On the roof directly above each end of the central corridor were located constant head fuel rooms; also on the roof, between cells Nos. 89-91 and Nos. 93-95, were oil weigh rooms, and between cells Nos. 97-99 was located an oil and fuel weigh room.

*This article is based on reports supplied to the NFPA by Mr. J. E. Frederickson, Director of Plant Protection, General Motors Corp.; by Mr. Robert R. Blackwell, Coordinator of Security, Allison Division, General Motors Corp.; and by Chief G. W. Barnes, Chief of the Allison Fire Department. The comments at the end of the article were inserted by the NFPA Executive Office to stimulate thought on the problems presented by the explosion. Reader comment is invited.

Allison News Photo

West end of Test Cell Building involved in the explosion. Test Cell No. 89, the one in which the fuel leak was detected, is at the extreme left in this picture. The building was of reinforced concrete construction with below grade areas throughout. Each pair of test cells had a common control room.

PROTECTION: The west block of 20-engine test cells, and the east block, were protected by a ten-ton, low pressure carbon dioxide system, complete with thermostatic (automatic) and manual (push button) controls.

USAGE: The cells were designed for piston type engine testing and had just been converted to jet type test cells. Cells Nos. 89, 91, 93, 95, 97 and 99 were in actual use for jet power plants. One cell (No. 107) was being prepared for use in development testing of a regenerative turbine engine using propane-air mixture for fuel but this fuel was not involved in the explosion (fuel system not being in service). One other cell (No. 96) was being used for storage of jet engines. The remainder of the cells in the block were not in use. Jet engines were actually installed in cells Nos. 89, 93, 95 (operating), 97 and 99 (all on the same side of the central corridor as No. 89). Ten other jet engines were stored on skids in cell No. 96.

FUEL SYSTEM: The fuel system was of the water displacement type consisting of sixteen underground storage tanks (15,000 or 25,000 gal. capacity each) having a total capacity of 320,000 gallons. This storage was divided into three types of jet engine fuel.* The underground delivery lines ran from the storage area to the wall of the adjoining building from which the supply pipe ran up the wall to the constant head room on the roof, where line pressure was reduced from the storage pressure of 50 psig, less line loss, to approximately 25 psig. The pipes went through the corridor roof from the header rooms and ran at ceiling elevation down the corridor with line take-offs adjacent to the common control rooms for each pair of operable test cells. Exterior, ground level hand operated and emergency shut-off valves were provided and each header room had, for each fuel system, manual and fusible type shut-off valves.

For the endurance type test cells (Nos. 89, 91, 93 and 95) the fuel piping entered the common control rooms and into an overhead fuel selection manifold. At this point, any of the fuels could be selected for either the afterburner or engine test cell systems. From the manifold, piping ran down the control room wall into the basement, with hand shut-off valves located in

*Army-Navy Spec. AN-F-48 100/130 grade; Army-Navy Fuel Spec. AN-F-48; Military Fuel Spec. MIL-F-5161A. (At time of explosion, no MIL-F-5161A was being supplied and lines for this portion were empty and purged.)

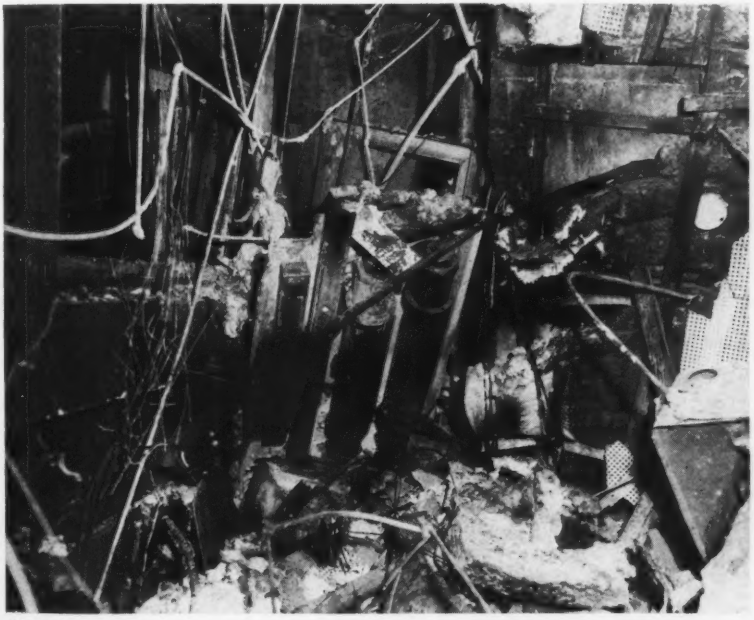
the control rooms. In the basement, the fuel was directed through fuel filters. The engine fuel was then directed up through flow meters (located on control desk panels), back down through the basement and, thence, into the test chamber to the engine platform. The afterburner system followed a similar pattern except the flow metering equipment was located in the test chamber, just outside the control room observation window. All cells (except No. 89*) had manual shutoff valves just upstream from the engine platforms. These normally closed safety valves could be operated manually from the control desk or would automatically close when the control master switch was closed. In the case of the afterburner system, this valve closed automatically when the exhaust equipment reached excessive temperatures. The propane mixing plant, located 75 ft. south of the test cell was being completed to supply this gas to test cell No. 107. It received little or no damage from the explosion.

The fuel involved in the explosion was found to have a flash point of –17°F, and an autogenous ignition temperature of 492°F.

*In cell No. 89, no hand operated valve was available at the engine platform. In this case a hand operated valve in the control room upstream from the fuel flow filter and flow meters, plus the air operated valve (mentioned above) were used to control the fuel. Consequently, procedure for shutting down stand system in cell No. 89 was to close hand-operated valve ahead of the fuel flow filters and fuel flow meter.

Sequence of Events on July 12

PREVIOUS TO THE EXPLOSION: At approximately 3:40 A.M. the plant protection



Allison News Photo

The fuel flow meter (glass tubes in center of picture) was where leak occurred. This equipment was in one corner of the control room between Cells Nos. 89 and 91. No explanations for the leak have been advanced.

officer at the headquarters switchboard received a telephone call from a man (presumably located in the test cell building) who reported a bad fuel leak near cell No. 89. He stated that fuel was running on the floor and into the basement area and requested a fire patrolman be sent to the area immediately. This fire patrolman was accordingly contacted in an adjoining building. Within two minutes he reported back stating that he had reached the scene, that the leak was at the fuel flow meter in the control room of cell No. 89 and he requested assistance. It is reported that the fire patrolman stated in this report that if a spark should ignite the vapors present it would "blow the place to hell." While further arrangements were being made (within three minutes) to bring the requested additional help, the explosion occurred (3:45 A.M.) which was heard all over the plant.

It is known that twenty minutes prior to the 3:40 A.M. discovery of the fuel leak, everything was normal in test cell No. 89. It is also known that at 3:20 the engine in test cell No. 95 was running at high speed. The 20-minute interval during which the fuel *might* have leaked could have discharged as much as 250 gallons per minute (under about 25 psig pressure) if one of the feeder lines had been completely open or broken. Since the valve to the fuel line leading to the meter involved was found closed following the explosion, it is presumed that one of the eight men in the building closed this valve between the time the fire patrolman reached the scene and the actual explosion.

Allison News Photo

The wreckage in the control room between Cells Nos. 93 on the left and 95 on the right. It was in No. 95 that a jet engine was running at the time of the blast. It is assumed that ignition of the explosive vapors occurred at this engine. The gasoline vapors were apparently drawn into this cell through the communicating basement level openings.

AFTER THE EXPLOSION: The explosion demolished the interior of 20 cells. Much of the explosive force went out through the roof and doors, leaving the walls of the cells almost entirely intact. The blast severed fuel lines leading to the cells (at each end of the building) causing a large quantity of fuel to be dumped into the cells. This spillage supported two terrific fires which were not extinguished but burned out after the exterior emergency valves in the main fuel supply lines were closed. Rescue work was delayed by these fires.

It was known that, during the midnight shift, seven employees (the smallest number on any shift) were assigned to the test cell (forty worked in the building during the day shift). It was also known that the fireman who requested assistance was in the building. One of the eight men unaccounted for was found badly injured and staggering outside the building but the other seven were presumed trapped. (The survivor died in the hospital 18 hours later.) The first bodies were recovered from the wreckage about 7:00 A.M., the last about 9:00 P.M.

Speedway and Indianapolis Fire Departments responded to calls for assistance along with local and state police. The fire fighting was of comparatively minor significance although 17 hose lines were laid and six pumpers were employed. The building protection, consisting of the 10-ton, low pressure carbon dioxide system was not significant because no fire preceded the explosion and the system was thus not activated.*

*Investigation revealed that the thermostats which operated the CO_2 system did not operate since there was no fire before the explosion. The wiring between the thermostats and the control panel did not short circuit when suddenly interrupted by the explosion. The push buttons were not operated and the master valve located at the tank was intact since the electrical supply to this area was not interrupted. When the master valve was opened the following day, the piping was twisted and pinched (by the explosion damage) so that CO_2 would not pass.

Immediately above this door on the extreme south test cell were fuel lines leading to the cell area. As a result of the explosion, these lines were ruptured and a severe fire developed as the door frame illustrates.

The explosive force was so great that the 6-inch thick concrete floor of the corridor was lifted as well as the roof (4-inch reinforced concrete) and both the roof and the floor dropped into the corridor tunnel.

In addition to the demolition of the 20 test cells, a steel-concrete roof deck was raised for a distance of approximately 100 yards east and north of the test cell area. Metal partitioning and air conditioning equipment was damaged for distances exceeding 150 yards. A steel door in a building 500 ft. away was blown partially open and badly sprung. A brick and concrete wall which butted against the test cell was moved approximately 5 inches.

There is no explanation as to why the serious leak occurred in cell No. 89 at the fuel flow meter. It cannot be stated whether this leak was a mechanical failure, a maintenance shortcoming or some other type of accident. Apparently the valves to the fuel flow meter were not closed prior to the discovery of the leak but all those known to be in the building were

killed and thus this point also cannot therefore be definitely determined. With the engine in operation in cell No. 95, it is easy to imagine that the gasoline vapors within their explosive range were drawn to this ignition source through the communicating basement level openings.

Comments

This explosion, the one at Hill Air Force Base on June 11, 1951* and the explosion of March 15, 1948 in an engine test stand building of the International Harvester Tractor Plant

*See footnote bottom next page.

Allison News Photo

The wreckage in the corridor, taken from south to north in the building, shows the floor and tunnel levels. Cell and control room doors opened from the grade level. Most of the bodies were recovered from this area.

(near Louisville, Ky.),† point to the need for some cooperative study on the problems associated with life and fire safety in engine test buildings. The NFPA might set up a special Committee to deal with the problem. Some of the items which should be considered are:

1. A method might be found to automatically detect fuel leakage from fuel supply lines or apparatus as soon as it occurs. Combustible vapor indicators in areas having such equipment might be effectively used. There may be need for development to increase the reliability of such indicators when installed in fixed locations. Warning devices designed to operate when fuel flows through piping, except when intended, might also be feasible.

2. A method to inert vapor hazardous areas might also be feasible and cells equipped with CO_2 flooding systems might utilize this protection for inerting (as well as smothering) in event of a spill or leak.

3. The actual need for basement, tunnel or other below grade spaces in engine test buildings might be investigated. They obviously afford convenient areas to house fuel and other service lines and their appurtenances but this equipment might more safely be run on the building exterior (under lightly constructed non-combustible cover, if desired). Basements are vapor traps which constitute a potential "bomb" in heavily constructed buildings of the type involved in this case. (Some new construction utilizes this exterior piping with entrance into the building through the roof and interior piping limited to the individual fuel control rooms.)

4. The use of reinforced concrete 100% throughout multiple test cell buildings of this type deserves study. Noise control and protection against engine disintegration (while under test) obviously enter into the problem but, other than in the engine test cell blocks themselves, there does not seem to be need for such excessive use of heavy construction which seriously aggrevates the explosion hazard. Corridor and control room roofs might be of light construction. Locating large numbers of engine test cells in a single building also deserves investigation. While such arrangements may be a convenience to operating personnel, the vulnerability factor is so high in case of accidental explosion or fire that smaller units would appear more desirable to assure continuity of production, especially under impetus of war preparedness. As minimum precautions it might be wise to omit openings between test cells and their control rooms or any below grade areas to prevent accidental vapor travel to such areas. Test cells might be accessible only from central corridors or outside areas and all interior doors might be self-closing but equipped with "panic bars."

5. Special drains adequate to take care of maximum anticipated flammable liquid spills might be provided in suitable areas where the spillage hazard exists (including cells). These drains would have to have fuel separators and means to drain fuel to safe disposal pits.

6. Constant pressure fuel supply systems (water displacement type) might not be the best method to deliver fuel to test cells. In this situation while only one engine was under test, all fuel lines in the 20-cell block were under 25 to 50 psig pressure. When the leak developed in an unused cell, 250 gpm under 25 psig might have spilled. At least sufficient fuel did spill to literally "flood" the building with a dangerous accumulation of explosive vapors. While pressure must be used to deliver fuel to the point of consumption, this force might be provided by positive operating pumps designed to apply pressure only to the lines (or line) in actual service at the point of fuel entry into the structure. If pressure is needed (gravity insufficient) to deliver fuel from the tank farm to this point, such pressure need not pressurize the entire system within the structure. Another solution might be a carefully engineered system of remotely operable valve controls to isolate all fuel piping not in actual use within the structure.

7. Fuel flow meters might be installed only on the downstream side of any booster pumps designed to increase fuel delivery pressures to the test stands. It seems desirable and feasible to isolate fuel flow meters from either the control room or the test cells.

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*Reference NFPA Special Airport Fire Bulletin, Series 1951, No. 3, available from the Association (25¢ per copy).

†No detailed NFPA report published. A report on this incident was prepared by the State Fire Marshal, Department of Insurance, Commonwealth of Kentucky, Frankfort, Ky., under date of April 3, 1948.

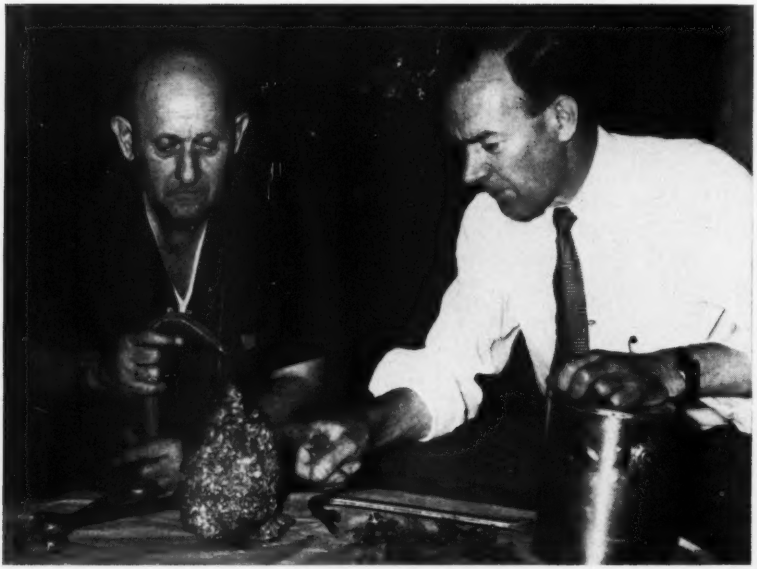
8. Greater attention and some research would seem warranted in regard to forced ventilation and explosion venting in buildings of this type. If massive concrete construction is required, explosion venting facilities at specially selected points, *i.e.,* roof hatches, might be possible, without interfering too seriously with the noise abatement problem. Forced ventilation at the floor level is desirable in rooms (other than test cells) where fuel spillage might occur.

9. In some relatively small but hazardous spaces (*i.e.,* fuel system tunnels), explosion suppression devices might be feasible* when and if they can be shown efficient for such applications.

10. Bulk storage of jet engines in test cell buildings is inadvisable.

*See NFPA QUARTERLY, July 1951, page 61.

Obstructions in Sprinkler Piping



The large chunk of lead weighing 15 pounds, with traces of oakum on it, and the small pieces totaling about 4½ pounds were found in an ell below the O.S. & Y. control valve, following the tripping of a dry pipe valve. Because the water pressure was so slow in building up after the valve tripped, our inspector realized something was wrong. When, upon checking, no evidence of a break in the underground mains was found, the system was drained and small particles of lead were noticed. When no other lead could be seen between the dry valve and the system O.S. & Y. valve, our inspector had the water supplies shut off and the seat removed from the dry valve. Upon probing, with the system gate valve open, the obstruction was discovered at the ell below the control valve.

Some months ago when an unsprinklered building was erected at this risk it was necessary to remove the post indicator valve and install an O.S. & Y. valve below the dry pipe valve. Instead of placing a flange on the bottom end of the short piece of pipe between the ell at the basement wall and the O.S. & Y. valve, the mechanic set the pipe in the flange on top of the ell and then attempted to caulk and solder the joint. This work was done by a person who was considered an experienced sprinkler mechanic of a reputable sprinkler concern, but it seems inconceivable that anyone could pour 20 pounds or more of lead on a 6-inch joint without wondering where it might be going.

KENTUCKY INSPECTION BUREAU.

Burning Characteristics of Building Materials*

By A. J. Steiner, Engineer
Underwriters' Laboratories, Inc.

Fire protection men know that building construction is of importance in the reduction of fire losses. Buildings are designed to contain fires within certain areas, by proper design and location of fire walls, by partitions having one, two, or four-hour fire-resistance ratings, by openings protected by wired-glass, steel-sash windows or tin-clad or sheet-metal fire doors, by the use of signalling devices to report incipient fires, by sprinkler systems and other automatic fire extinguishing systems, or by fire extinguishers until the fire department arrives.

The records show that these safeguards have been successful. In recent years, however, large numbers of well-designed buildings have been remodeled and modernized. The walls of these "improved" buildings have been "treated" to change their appearance, to provide for acoustical correction, to afford insulation properties or to subdivide large areas for various reasons. Fire experience has shown that these changes have markedly upset the planned fire safety of the original structure, especially in cases where certain kinds of building materials were used.

After fires in such remodeled buildings, it has not been uncommon to hear someone say: "That was a bad fire, it spread fast, faster than fires have in the past" or "It was a flash-over fire." The basic cause for the rapid spread of such fires seems to have been a mystery to many people. Some have placed the blame on new types of finish, lacquer, or paint. In my humble opinion, it has been that many of the new materials used in building remodeling spread fires under certain conditions more rapidly than materials with which we have been accustomed.

Fire Experience Justified Tests

May I remind you of some recent fast spreading fires where it is documented that they started in a location where certain kinds of materials were used in the remodeling or redecorating of existing, well-constructed or so-called fire-resistive structures.

The Chicago LaSalle Hospital fire,* in which many lives were lost, apparently started in a room remodeled with building boards applied with concealed air spaces behind them. As you know, the fire spread very rapidly into the lobby area where the walls had wood paneling. Some of this paneling was brought to Underwriters' Laboratories and in a test developed by them (which I will describe), it was demonstrated that the rate of spread of fire on the panel surface was 5½ times as fast as it would have been had the paneling been solid oak. Why? Because it was veneered paneling and not because it had too much varnish or lacquer finish. The test showed that when the paneling was heated, the veneer peeled and the thin, loose, paper-like sheets spread fire rapidly. In this fire extra oxygen required to sup-

*Based on a talk and demonstration presented at the 55th Annual Meeting of the NFPA held in Detroit, Michigan, May 7-11, 1951 (Program Item No. 69) and at the 23rd Annual Fire Department Conference held in Memphis, Tenn., Jan. 11, 1951. *Firemen* magazine, also published by the NFPA, printed excerpts from Mr. Steiner's talk in April 1951.

*See NFPA *Quarterly*, July 1946, for complete details.

Chicago Tribune

The delamination of the varnished walnut veneer panels in the lobby of the LaSalle Hotel, which were found on tests after the fire to burn five times as rapidly on the surface as ordinary red oak lumber.

port combustion was obtained from the hallway on upper floors where the doors were not properly closed. These hallways served as air ducts denying the occupants on upper floors the oxygen needed to support life. Sixty-one persons lost their lives in this tragedy, many by asphyxiation.

Thus, there was nothing so fantastic about this tragic fire in 1946 except that the arrangement of building materials was such as to produce the flash conditions. Similar fires, since the LaSalle disaster, have confirmed this premise.* Undoubtedly many of you appreciate that like conditions exist today in buildings with which you are familiar. If certain conditions exist, serious fires may also occur in these structures.

Other serious fires which should be noted are the Cocoanut Grove disaster (1942)* in Boston in which decorations were responsible for rapid flame spread and the St. Anthony Hospital fire** where the acoustic tile placed on the walls and ceilings of the hallways played their part. Industrial buildings of steel frame enclosed with corrugated steel coated with asphalt were, for many years, not considered as having serious fire hazard characteristics, but in recent years a number of bad fires have occurred by rapid spread of flames over such surfaces.†

There may be some excuse for past performances because no reliable method of evaluating how fire spread on building materials has been developed until recently. As these new materials came into use Underwriters' Laboratories realized the pressing need for answers to questions on the burning characteristics of these new types of materials.. We received many samples of materials with questions, "How will this burn?" or "Is this combustible?" or "How will this burn in comparison with wood?" These are difficult questions to answer unless you have a proper test method to compare the burning characteristics with materials such as wood or other commonly used materials.

*See NFPA *Quarterly*, October 1949, for article by Robert S. Moulton on "Combustible Fibreboards."

*See NFPA pamphlet "The Cocoanut Grove Night Club Fire" (20 pages) available from the NFPA Publications Service Dept. (25¢ per copy.)

**See NFPA *Quarterly*, July 1949, for complete details.

†See, for typical examples, fires of May 6, 1945 in Columbus, Ohio and June 25, 1945 in Detroit, Mich. (Jan. 1946 NFPA *Quarterly*, p. 184 and 185), fire of Mar. 5, 1946 near Baltimore, Md. (Jan. 1947 *Quarterly*, p. 203), and fires of Mar. 10, and two of May 2 at Etna, Pa., Weirton, W. Va., and Miami, Fla. (Jan. 1951 *Quarterly*, p. 202, 203 and 207 respectively).

The Test Method

The test method we have developed is very simple. It is based on the fact that wood, under certain conditions, will spread fire and cement and concrete will not. In our test we have demonstrated that some species of wood will spread fire faster than others and that the moisture content of wood is an important factor. We have also demonstrated that veneered lumber may spread fire five times or more faster than oak, as was the case of the paneling in the LaSalle Hotel fire, as previously mentioned. It is most important to realize that in order to compare the burning characteristics of different materials, it is necessary to test them under identical conditions. Obviously, no material will burn unless it is heated to its ignition temperature. The moisture content of the material, the rate of air travel over the exposed surface and the size or intensity of the exposing fire in relation to the material to be ignited are all conditions which must be standardized if comparison tests on different materials are to be valid.

In our tests, all materials are conditioned to a moisture content stability under standardized conditions of approximately 70°F and 35 per cent relative humidity. The test conditions, that is, the air travel and moisture content of the air and the size and intensity of the fire, are regulated so as to permit wood to burn. A good example for the necessity of control to attain ignition can be illustrated by the difficulties sometimes experienced in obtaining ignition in your automobile. The tank may be full of gasoline, the battery

Underwriters' Laboratories, Inc.

Figure 1. The test furnace developed by Underwriters' Laboratories, Inc. for comparing the burning rates and related data on various types of building materials. Here the 20 ft. long specimen (in this case, tongue and groove wood flooring) is being placed in position on the top of the furnace. The 4½ ft. gas flame used in the furnace creates a temperature of 1415°F. The size and intensity of the flame was selected so that flame would cover the entire surface of red oak in about 5½ minutes.

in first-class shape, the spark plugs producing a good spark, but the engine will not start unless the carburetor is properly adjusted. You cannot get ignition in your engine unless all conditions are right within reasonable limits. The same thing holds good for ignition of building materials.

My theory is that more fires, more bad fires, occur in buildings during the heating season because all combustible materials have been dried and the moisture in the air is less and, therefore, materials will ignite easier and burn faster. The conditions are more favorable to ignition.

The Test Furnace

The test surface is 20 ft. long, 20 in. wide and is mounted to form the top of a long rectangular insulated tunnel. The air passing through this tunnel is regulated to about 200 ft. per minute. One end of the test surface is exposed to a flame created by about 7 cu. ft. of gas per minute. This flame is about 4½ ft. long, creating a temperature of about 1400° to 1550°F. The size and intensity of the exposing flame was developed after experiments and repeated tests that the fire will spread on a red oak surface and that the results can be repeated.

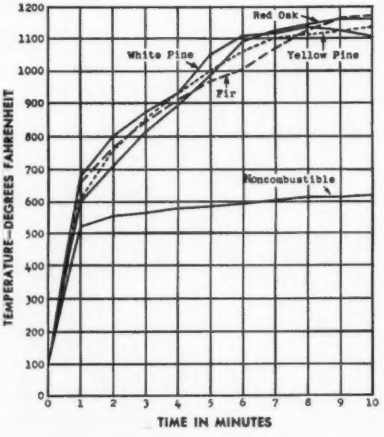


Figure 2. The amount of fuel contributed by the various materials specified are shown. Data taken from such curves are used to produce a workable scale for classifying the relative hazard of materials under the test procedure developed by Underwriters' Laboratories.

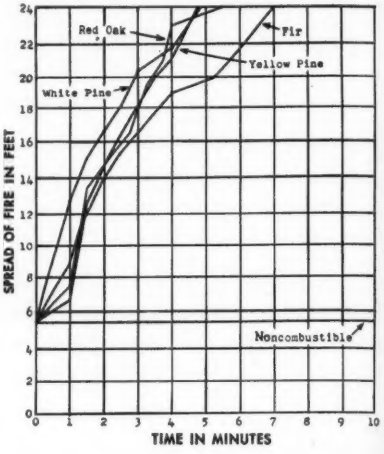


Figure 3. The rates of flame spread for five materials are shown to be gradual, but the rate increases as the time of exposure lengthens. The difference in the extent of the flame spread on the various materials tested and, to some extent, the time elements involved, provide a guide for classifying the materials (100 for red oak, 0 for cement asbestos board).

These conditions are not optimum fire conditions, but were selected so as to produce a flame spread on the wood surface at such a rate that the entire surface would be in flames in about 5½ minutes. We could change the conditions so that the flames would spread in a minute-and-a-half to two minutes over the surface, but it would be too fast to give us time to make the desired observations on such details as the temperatures and quantity of smoke developed. The smoke is measured by the intensity of an electric light beam on a photoelectric cell through the duct running from the furnace to the stack and through which the smoke passes. The variations in the density of the smoke are

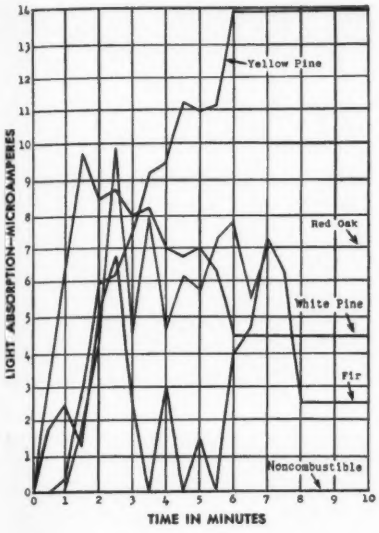


Figure 4. The density of the smoke produced by the various materials is indicated. Note that the noncombustible cement asbestos board registered "zero" while the amount of smoke produced by other materials varied according to the time element and the nature of the material.

recorded. We have also made provisions for taking samples of gases during the test for examination as to its toxicity.

We have found that 10 minutes exposure was sufficient to provide us with complete information needed as to the burning characteristics of the materials. During this time three properties are recorded, namely, the *rate of spread of fire,* which is done by observing the time that the flame is seen progressing along the surface; second, the *fuel contributed to the exposing fire,* by recording the temperatures as developed at the end of the tunnel opposite the exposing fire; thirdly, the *density of the smoke and the toxicity of the products of combustion.* By recording these details under standardized conditions, the results provide a basis of 100 and 0 points on a scale in tests on red oak and cement asbestos samples, respectively.

Figures 2, 3 and 4 present data developed with tests on red oak, white pine, fir, yellow pine and cement asbestos board as to the fuel contributed, the rate of flame spread, and smoke density.

Results of Tests

By using this test method, we have shown that untreated fabrics, like folded muslin as sometimes used for decorative purposes in places of assembly, will spread fire to earn a classification of 2000, which means that the fire will spread twenty times as fast as on red oak. Similarly, we have observed that the vapor seal on the face of some insulating materials will spread fire 25 to 30 times faster than that on the surface of red oak. Materials of this latter type are used in insulating homes and I venture to say that if a person went into an unfinished attic of a house which had the roof insulated with such materials, that person might be trapped if the material were ignited.

You undoubtedly recall serious fires in bowling alleys* and in some cases lives were lost because fire spread rapidly.** In such fires, the principal blame has been directed to the finish on the floors, to the lacquer on the pins and to the hazards existing in refinishing rooms.

It seems that the materials on the walls and ceilings have been overlooked. My investigation indicates, however, that the building materials used, the concealed spaces behind false ceilings and walls, and the air currents in such buildings have been major factors in the rapid spread of fire in a number of bowling alley fires, including those causing loss of life.

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*See NFPA pamphlet "Bowling Alley Fires" (August 1944) available from the Association (25¢ per copy).

**Fire of Jan. 5, 1943 in Chicago, Ill., reported in the NFPA pamphlet referenced above, is the most serious bowling alley loss-of-life fire reported to the NFPA (8 killed).

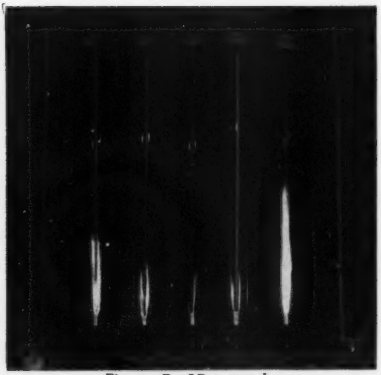

Figure 5. 35 seconds.

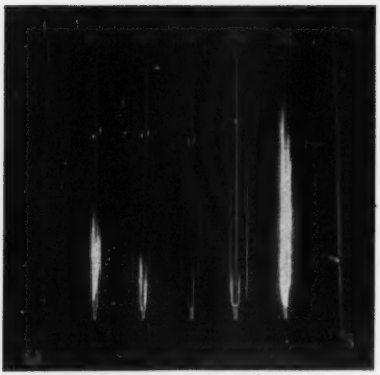

Figure 6. 60 seconds.

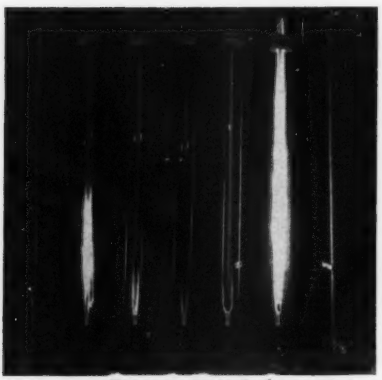

Figure 7. 90 seconds.

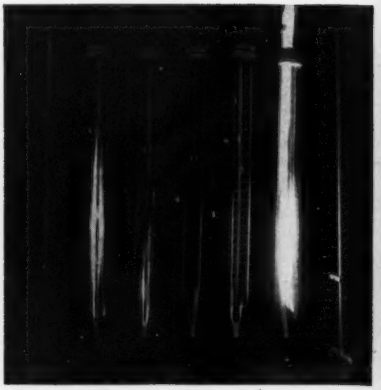

Figure 8. 120 seconds.

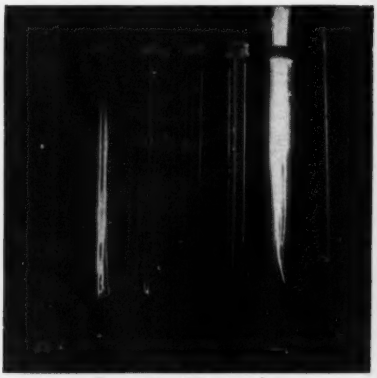

Figure 9. 150 seconds.

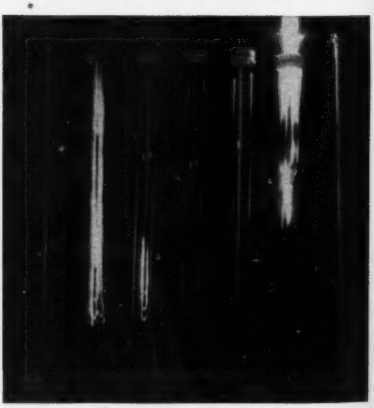

Figure 10. 180 seconds.

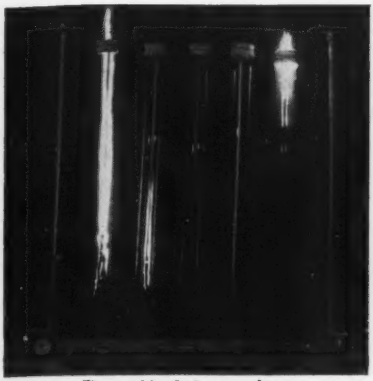

Figure 11. 210 seconds.
Underwriters' Laboratories, Inc.

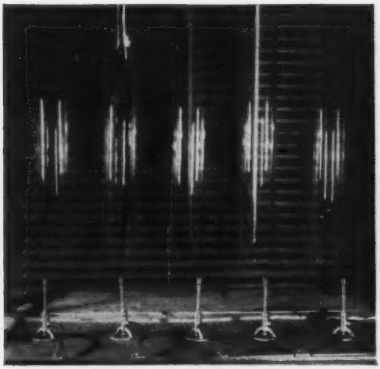

Figure 12. 340 seconds.

Figures 5-12 illustrate a demonstration conducted by Mr. Steiner to show how the same material will burn differently under similar fire conditions. Five samples of the same kind of wood, of the same size (⅜ inch thick by ¾ inch wide), were placed in glass tubes and subjected to the same size and intensity of fire for the same length of time.

The different results obtained in burning occurred because of the condition of each sample. In each picture, reading from left to right, the samples of wood were as follows:

(1) This piece was dried to a moisture content of 7 to 10 per cent similar to what would be found in a building during the heating season;

(2) This piece had about the same amount of moisture that would be contained in wood in a building or an industrial establishment under high humidity conditions;

(3) This piece has been *impregnated* with a UL listed "fireproofing" compound throughout its cross-section with the intent of keeping wood from spreading fire;

(4) This piece of wood was *painted* with a UL listed so-called "fireproof" paint or coating;

(5) This piece is the same as (1) except that it is *laminated*. Delamination occurred under the heat exposure.

Conclusions

Our test results provide a tool for judging how a material will burn in comparison with wood when exposed to similar fire conditions.

We urge that new materials created for use in building construction be classified as to their burning characteristics to assist those authorized, to regulate, to reduce, or even to eliminate such fire catastrophes as we are now experiencing.

Halogenated Extinguishing Agents

Based on Material Prepared By
Drs. R. C. Downing and B. J. Eiseman, Jr., Jackson Laboratory
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and
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EDITOR'S NOTE: In presenting the information herein, the NFPA is reporting authoritative research conducted by the two Laboratories. The opinions expressed in connection with these research data are those of the authors.

It should be emphasized that research is continuing on these and other extinguishing agents (particularly aqueous solutions of alkali earth metal salts) at various Laboratories in the United States. Practical fire tests utilizing these halogenated agents have not been completed. The relatively low autogenous ignition temperatures of many of the halogenated compounds present some additional problems, the significance of which has not been completely evaluated.

Readers are further cautioned in appraising the technical information presented that practical considerations of actual fire extinguishment must be blended with these laboratory results. Such considerations as rates of discharge, range effectiveness of the agents, suitability of agents for all types of fires (including Class "A"), optimum methods of discharging the selected extinguishing agents, and, last but not least, the cost and availability of the chemicals chosen. The manner in which any fire extinguishing agent is employed and the environment of the application has a profound effect on its efficiency. Laboratory researches cannot evaluate these factors adequately in many cases.

As further data become available the NFPA will publish the information to keep its members properly advised.

The information published in Part II by Mr. Malcolm is based on a talk given by the author at the 55th Annual Meeting of the NFPA in Detroit, Michigan, May 7-11, 1951.

Part I
Research at the Jackson Laboratory

By Drs. R. C. Downing and B. J. Eiseman, Jr.

The science of fire fighting is, to a certain extent, built around the character of the fire extinguishing agents that are available and, in some instances and for some purposes is limited by defects in the agents. This is especially true for small fires ordinarily served by hand equipment and for various types of fires occurring in aircraft. Commonly used extinguishing agents presently employed are useful in many ways but, at the same time, have certain limitations.

It is doubtful if anything can replace water, foam or carbon dioxide for certain types of fires. Carbon dioxide as used in aircraft has restrictions because of the weight penalty of the high-pressure cylinders required and because it has some

physiological activity. Carbon tetrachloride, one of the most commonly used extinguishing agents today, has considerable toxicity, is quite corrosive and is relatively low in effectiveness. Methyl bromide is one of the most effective agents available but has found very little general use because of its toxicity and corrosiveness. Chlorobromomethane, generally known as "CB," has been proposed as the "perfect" agent but does not seem to be the final answer from the standpoint of its toxicity, stability, effectiveness and its spontaneous ignition temperature.

Shortly after the close of World War II the Jackson Laboratory of the E. I. du Pont de Nemours & Company was approached by one of the leaders in the fire extinguisher industry (Walter Kidde & Company, Inc.) with a request for a fire extinguishing agent more effective and stable and less toxic than any known at that time. A review of the subject indicated that one or more halogen atoms were necessary for effective extinguishing ability and that the effectiveness decreased from iodine to bromine to chlorine. For example, in carbon tetrachloride there are four chlorine atoms, in methyl bromide there is one bromine atom and in "CB" there is one bromine and one chlorine atom. Our past experience with fluorine in organic compounds pointed to the need for the fluorine atom to give the compound stability and low toxicity. Since iodine is in relatively short supply in the world, the combination of bromine and fluorine atoms in the same compound seemed most promising.

The Armed Forces, especially the Corps of Engineers and the Air Force, have undertaken extensive testing programs in the laboratory and in the field with these new halogenated fire extinguishing agents. Mr. H. A. Klein of the Air Force summarized the developments in his branch in the April 1950 NFPA *Quarterly* and the work of the Corps of Engineers is described in Part II of this presentation on the subject, prepared by Mr. J. E. Malcolm.

It is the purpose of this report to present to NFPA readers some of the results of our experience over the past few years with these compounds.

Effectiveness of Halogenated Agents

Our laboratory has conducted some comparative tests of these halogenated fire extinguishing agents with some of the commonly used agents and the resulting data are listed in Table I. The data on agent effectiveness were measured in a standard 100 cc explosion pipette (about one inch in diameter and thirteen inches high) using mercury for the containing liquid. Ignition was supplied by platinum electrodes in the top of the pipette so that the direction of flame propagation was downward. A mixture of methane (9.9 volume percent) and air (90.1 volume percent) was used as the explosive test mixture to which a known volume of extinguishing agent was added. The concentration of the agent was adjusted either by adding fresh portions of the explosive mixture or by making up a new mixture for each extinguishing agent concentration being tested. The gases were mixed by transferring them to the pipette and back to the make-up flask eight to ten times before testing the flammability. The concentration of the methane and extinguishing agent was obtained by measuring the pressure of the mixtures. An average of the agent concentration that just prevented burning and the amount present when combustion first occurred was used to measure its effectiveness.

The method outlined above was intended to compare the *relative effectiveness* of the fire extinguishing agents tested under standardized conditions. It is evident from previous work by the Bureau of Mines* that for *reliable determination of flammable limits* a carefully designed apparatus with a larger combustion tube and upward propagation of the flame should be used. The exact correlation between the explo-

*U. S. Dept. of the Interior, Bureau of Mines, Bulletin 279, Gov't. Printing Office 1939.

TABLE I

Comparative Effectiveness of Selected Halogenated Fire Extinguishing Agents Tested by the Jackson Laboratory of the du Pont Company

Agent		Halon No.*	Effectiveness Vol. %	Effectiveness Wt. %	Boiling Point Degrees F.
Bromochlorodifluoromethane	$CBrClF_2$	1211	0.5	2.9	25
Dibromodifluoromethane	CBr_2F_2	1202	0.5	3.7	76.1
1, 2-Dibromo-2-chloro-1,1,2-trifluoroethane	$CBrF_2CBrClF$	2312	0.6	5.7	200
1,2-Dibromo-2,2-difluoroethane	$CH_2BrCBrF_2$	2202	0.6	4.6	200
Methyl bromide	CH_3Br	1001	0.8	2.7	40
Ethylene dibromide	CH_2BrCH_2Br	2002	0.8	5.2	269
1,2-Dibromotetrafluoroethane	$CBrF_2CBrF_2$	2402	0.85	7.4	117.5
Hydrogen bromide	HBr	....	0.9	2.6	−88.5
Methylene bromide	CH_2Br_2	1002	0.9	5.4	209
Chlorobromomethane	CH_2BrCl	1011	1.0	4.5	156
Bromotrifluoromethane	$CBrF_3$	1301	1.1	5.6	−76
Bromodifluoromethane	$CHBrF_2$	1201	1.2	5.4	5
Dichlorodifluoromethane	CCl_2F_2	122	2.1	8.6	−21.6
Carbon tetrachloride	CCl_4	104	2.5	12.5	170

*Halon numbers are designed for convenient and quick reference to the numerous chemical compounds listed. The first digit of the number represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; the fifth digit, the number of iodine atoms. In this system terminal zero digits are not expressed, in other words, dichlorodifluoromethane (CCl_2F_2), or "Freon 12," is termed Halon 122.

sion prevention type of test and tests in which a fire is actually extinguished has not been well established and in the final evaluation of new extinguishing agents fairly large scale tests with a fire should be made. With these qualifications in mind, the following results of our pipette tests offers a preliminary indication of the effectiveness of the agents selected for test.

The order of effectiveness shown here varies somewhat from the data previously published† and from that appearing in Mr. Malcolm's article (see Table X) due to differences in the laboratory methods of evaluation. It will also be noted that some of the above listed agents are not included in the other references. Despite these differences, however, the general superiority of the bromofluoro compounds is clearly illustrated.

In further reference to Table I, note that the effect of the bromine is consistent and tends to increase the effectiveness of the compound. For example, a comparison of CCl_2F_2 (Halon 122) and $CBrClF_2$ (Halon 1211) indicates that the replacement of Cl with Br has considerably improved the compound as an extinguishing agent. When Br is substituted for H as in $CHBrF_2$ (Halon 1201) and CBr_2F_2 (Halon 1202), there is again an improvement. However, if one Br atom is already present in the molecule, the addition of another Br is not always beneficial, as in the case of CH_3Br (Halon 1001) and CH_2Br_2 (Halon 1002) or $CBrClF_2$ (Halon 1211) and CBr_2F_2 (Halon 1202).

The presence of fluorine in the molecule tends to increase the stability and reduce the toxicity of the compound and, in some cases, has a desirable effect on the use of the compound as an extinguishing agent. Considerable improvement was found in CBr_2F_2 (Halon 1202) compared with CH_2Br_2 (Halon 1002) and in $CBrClF_2$ (Halon 1211) compared with CH_2BrCl (Halon 1011). The decrease in effectiveness of $CBrF_3$ (Halon 1301) over CH_3Br (Halon 1001) may be explained by the

†See April 1950 *Quarterly*, page 238.

unusually great stabilizing effect of the CF_3 group. In the ethane series, represented by $CBrF_2CBrF_2$ (Halon 2402), $CH_2BrCBrF_2$ (Halon 2202) and CH_2Br-CH_2Br (Halon 2002), the substitution of F or H had but little effect on the extinguishing ability of the compound, although there was a large increase in the stability and decrease in toxicity in the fluorinated compounds.

Physical Properties of Fluorinated Agents

In Table II some physical properties of a few of the fluorinated compounds are listed. The unusual combination of high liquid density and low-boiling point which is a general characteristic of the fluorinated compounds is well illustrated. This effect is especially noticeable in the bromofluoro compounds such as CBr_2F_2 (Halon 1202) where the high concentration of bromine greatly increases the weight while the presence of the fluorine keeps the boiling point down.

For example, CBr_2F_2 (Halon 1202) with a boiling point of 76.1°F has a density of 2.278 g/cc or 19 lbs/gal while the similar compound with hydrogen, CH_2Br_2 (Halon 1002), with a slightly higher density of 2.5 g/cc or 20.5 lbs/gal has a much higher boiling point (209°F). This combination of properties in the halogenated agents greatly reduces the storage

TABLE II

Physical Properties of Some Extinguishing Agents Tested by the Jackson Laboratory

Name	Chemical Formula	Halon No.[1]	Boiling Point °F	Freezing Point °F	Viscosity Centistokes[2]	Liquid Density g/cc[3] 70°F	Liquid Density g/cc[3] 130°F	Critical Temp.[4] °F	Estimated Pressure psig 130°F	Estimated Pressure psig Critical
Bromochlorodifluoromethane	$CBrClF_2$	1211	25	−257	....	1.826	1.695	308.8	75	595
Dibromodifluoromethane	CBr_2F_2	1202	76.1	−112	....	2.278	2.152	388.7	23	585
Bromotrifluoromethane	$CBrF_3$	1301	−76	−356	....	1.58	1.249	152.4	460	620
1,2-Dibromo-1,1,2,2-tetrafluoroethane	$CBrF_2CBrF_2$	2402	117.5	−166.8	0.34 77°F	2.166 77°F	....	....	3.8	....
1,2-Dibromo-2-chloro-1,1,2-trifluoroethane	$CBrF_2CBrClF$	2312	200	....	0.64 77°F	2.226 77°F	....	....	22.2[5]	....

[1] See explanation of Halon No. in footnote, Table I, page 112.

[2] Measured by Ostwald viscosimeter. For comparative purposes, ethyl alcohol has a viscosity of about 1.5 centistokes at the indicated temperature.

[3] The liquid density was measured for each of the low boiling compounds at two different temperatures by using calibrated glass floats sealed with liquefied gas in glass pressure tubes. The temperature was altered until the glass float neither sank nor rose, at which point the liquid and the float have the same density. The experimental values were then applied to an average orthobaric density curve prepared from data on various "Freon" fluorinated hydrocarbons. From this curve, the critical density could be obtained as well as values at any lower temperature such as those at 70°F and 130°F shown in the table. For the compounds boiling above room temperature, the weight of a given volume of liquid was determined.

[4] In order to find the critical temperature a sample of the compound was sealed in a heavy-walled glass tube and heated until the liquid phase disappeared.

[5] Inches of mercury vacuum.

volume requirements for a given weight of material without sacrificing the low boiling point that seems beneficial in fire extinguishing agents.

Another effect of the presence of the heavy bromine atom or atoms is a relatively high molecular weight and consequently a high vapor density. A heavy vapor is especially desirable in an extinguishing agent so that it will tend to settle down near the base of a fire.

The advantage of a low viscosity value shows up in the flow, pumping and spraying characteristics of the agent.

Two other physical properties that may be of interest or value in studying the behavior of fluorinated extinguishing agents are the heat of vaporization (Table III) and the heat capacity of the vapor (Table IV).

TABLE III

Heat of Vaporization at the Boiling Point of Selected Agents — Research by Jackson Laboratory

Agent	Halon No.*	Latent Heat of Vaporization Cal/gram mole	Cal/gram (Btu/lb)†
CBr_2F_2	1202	6100	29
$CBrClF_2$	1211	5300	32
$CBrF_3$	1301	4200	28
$CHBrF_2$	1201	5100	39
CH_3Br	1001	5880	62

*See explanation of Halon No. in footnote, Table I, page 112.

Note: The heat of vaporization was calculated by the Clapeyron equation from the slope of the vapor pressure curve. The pressure curve was constructed from the boiling point and a comparison with other fluorinated compounds. The vaporization data are believed to be about ±5% accurate.

†For comparison purposes water has a latent heat of vaporization of about 540 cal/gram and carbon dioxide 138 cal/gram. Although it is noted that the heat of vaporization of water and carbon dioxide is considerably higher than the halogenated extinguishing agents, this is not considered important in the action of the latter since the halogenated agents reach the base of the fire already vaporized and experimental data indicates they are effective not because they remove heat from the fire but rather because they terminate the chain reaction occurring during combustion.

TABLE IV

Molar Heat Capacity at Constant Pressure of Selected Agents — Research by Jackson Laboratory

Agent	Halon No.*	Temp. °F	Heat Capacity Cal/gram mole/°C Vapor	Liquid
CBr_2F_2	1202	77	....	32
		85	18.6	
		200	19.9	
		400	21.6	
		600	22.8	
$CBrClF_2$	1211	77	....	30
		85	17.7	
		200	19.2	
		400	21.0	
		600	22.4	
$CBrF_3$	1301	77	....	30
		85	17.2	
		200	18.9	
		400	20.9	
		600	22.3	
Water†	....	77	....	75
		212	36.3	
		248	35.9	
		320	35.6	
		392	35.5	
		592	35.9	
Carbon Dioxide†	....	–98	....	56
		212	38.4	
		392	40.2	
		572	42.2	

*See explanation of Halon No. in footnote, Table I, page 112.

†This information is included for comparison purposes only.

Note: The heat capacity of CBr_2F_2 vapor was calculated from spectrographic measurements, a method generally considered more accurate than direct measurement. The values for the other compounds were determined by empirical methods and may not be better than 10% accurate. The liquid heat capacity values may not be more reliable than to ±20% since they were obtained by comparison with other compounds.

This heat capacity data may be of value in relation to the use of fire extinguishing agents in the following ways. If the agent is loaded into the dispersing apparatus at atmospheric pressure, the heat capacity of the liquid and the heat of vaporization will be important. If, however, the agent is loaded into the dispersing apparatus under pressure, the heat quantities will be of little significance. Likewise, during discharge the heat effects will have little

TABLE V
Utility of Heat Capacity Data
Research by Jackson Laboratory

Agent	Halon No.*	Loading: Under Pressure	Loading: (Open System)	Discharge: Pressurized or Pumped	Discharge: Autogenous Pressure Liquid	Discharge: Autogenous Pressure Gas	At Fire: Liquid Stream	At Fire: After Vaporization
CBr_2F_2	1202	....	(C_LH)	....	....	....	(C_L)H	C_g
$CBrClF_2$	1211	....	C_LH	....	....	....	H	C_g
$CBrF_3$	1301	....	C_LH	....	(C_LH)	C_LH	H	C_g

*See explanation of Halon No. in footnote, Table I, page 112.

Note: Information in parenthesis means small or doubtful utility.
C_L means specific heat of the liquid.
C_g means specific heat of the gas.
H means latent heat of vaporization.

application if the propellent is a gas or if the liquid is mechanically discharged. For liquefied gases discharged liquid phase under their own vapor pressure, there will be a small cooling effect due to vaporization in the containers. If, for some reason, the liquefied gas were discharged vapor phase the cooling effect of the vaporization in the container would be large. In this latter case, since the cooling effect in the container is appreciable, the design engineer must consider this fact since the cooling would lower the discharge pressure and thus reduce the effectiveness of the extinguisher. This handicap can, of course, be overcome by pressurizing the extinguisher with a gas. If the extinguishing agent reaches the fire as a liquid, the heat of vaporization is of interest and after vaporization the heat capacity of the gas may be important. Table No. V presents this information in tabular form.

It might be said, in summary, that these halogenated agents do not extinguish fires by reason of their cooling effect. It is not proposed that they will be effective agents for reducing surface temperatures of heated masses in the presence of flammable atmospheres.

Stability

In order to determine the stability of the fluorinated fire extinguishing agents when stored in metal containers, several series of tests have

TABLE VI
Penetration of Metals in Sealed Tube Tests of Selected Agents — 260 Days at 120°C
Research by Jackson Laboratory
Average Penetration, (in./mo.) X 10^{-6}

Compound	Halon No.**	Steel: Dry	Steel: Wet*	Brass: Dry	Brass: Wet*	Aluminum: Dry	Aluminum: Wet*
$CBrF_3$	1301	0.9	–91	1.5	–35	0.7	59
CBr_2F_2	1202	0.8	62	0.7	375	0.7	55
$CHBrF_2$	1201	1.1	78	8.5	300	0.3	50
$CBrClF_2$	1211	1.1	82	6.	435	0.8	54
$CBrF_2CBrF_2$	2402	1.5	140	5.7	385	0.4	50
$CBrF_2CBrClF$	2312	2.4	125	370	1175	–0.1	–8.3
CCl_4	104	1.5	93	8.7	215	>1500.	54.
CH_3Br	1001	42.0	650	310	250	>1500.	>1500.
CH_2BrCl	1011	27.0	280	200	1620	>1500.	>1500.

*Three volume percent water.

**See explanation of Halon No. in footnote, Table I, page 112.

–Represents tightly bound scale forming in layers on the metal test strip rather than corrosion or penetration.

been run comparing six compounds (bromofluoromethanes and ethanes) with carbon tetrachloride, methyl bromide and chlorobromomethane ("CB"). Each of the liquids was sealed in glass pressure tubes with a metal strip, both anhydrous and with added water. Steel, brass and aluminum were the metals tested. The fire extinguishing liquids were of commercial quality. The results reported are in most cases the average of several tests.

These tubes were stored at 120°C for 260 days, and were frequently inspected during this period to follow the deterioration of the liquid and the corrosion of the metal strip. At the end of the test, the tubes were broken and the penetration of the strip determined. The penetrations ranged from less than 1 x 10^{-6} inches per month to more than 1500 x 10^{-6} inches per month (Table VI).

The advantage of fluorine in the compound, from the standpoint of stability, is readily apparent. In all cases the corrosion was much worse in the presence of water, especially for brass. Steel seems to be the most acceptable metal, considering both dry and wet tests and all of the agents used. The corrosion of aluminum was less than that of steel for the fluorinated compounds but it was severely attacked by the compounds that did not contain fluorine.

In addition to corrosion of the metals the stability of the extinguishing agent was evaluated according to the evidence of decomposition in the liquid. An empirical scale showing changes in the condition of the liquid was used to indicate the degree of decomposition as shown in Table VII. Here again the fluorinated compounds appear more stable than the compounds that do not contain fluorine.

Pressurized Fluorinated Agents

The low freezing points of these fluorinated compounds make them suitable for use in sub-zero temperatures and there has been considerable interest in this application, especially in self-propelled systems. Such a low temperature system must also function properly without developing unsafe pressures at high ambient temperatures. More particularly the requirements for a low temperature self-propelled system (in addition to low toxicity and high stability) are:

1. High enough pressure for discharge at low temperature (100 to 200 psig at minus 65°F).

2. The pressure must be well maintained during the entire discharge.

TABLE VII

Appearance of Selected Agents in Sealed Tube Tests after 260 Days at 120°C*
Research by Jackson Laboratory

Compound	Halon No.**	Steel		Brass		Aluminum	
		Dry	Wet	Dry	Wet	Dry	Wet
$CBrF_3$	1301	0	0	0	0	0	0
CBr_2F_2	1202	0.5	0	0	0.5	0	1
$CHBrF_2$	1201	0	0	0	0	0	0
$CBrClF_2$	1211	0	0	0	0	0	0
$CBrF_2CBrF_2$	2402	0.5	1.5	0.5	1.5	0	0
$CBrF_2CBrClF$	2312	1	1	1	1.5	0	0.5
CCl_4	104	1.5	3	1	3	3	1
CH_3Br	1001	2	3	2	3	3	3
CH_2BrCl	1011	3	3	3	3	3	2

*Changes in the appearance of the liquid were evaluated by the following classification:
0 means no change.
1 means that a yellow or light amber color developed during the test.
2 means that the liquid was dark amber or black or had completely disappeared after 100 days or more.
3 means that the liquid had become dark or had disappeared in less than 100 days.

**See explanation of Halon No. in footnote, Table I, page 112.

TABLE VIII

Selected Self-Propelled Fire Extinguishing Mixtures Tested at Jackson Laboratory

Substances	Halon No.*	Composition of the Liquid Phase Weight Percent	Mole Percent	Approximate Vapor Pressure, psig at Indicated Temperatures, °F −65°	+77°	+130°	+150°	Number of Container Volumes** of Propellent at minus 65°F and 100 psig
CBr_2F_2 with "Freon-14"	1202	95.0 5.0	88.8 11.2	200	430	490	520	3.0
CBr_2F_2 with nitrogen	1202	99.8 0.2	98.6 1.4	200	285	345	370	0.7
CBr_2F_2 with nitrogen	1202	99.7 0.3	98. 2	300	415	490	520	1.0
$CBrF_3$ with "Freon-14"	1301	68.3 31.7	56 44	200	845	(1200)	(1350)	6.3
$CBrF_3$ with nitrogen	1301	99.6 0.4	97.8 2.2	200	425	(685)	(885)	1.5
$CBrF_2CBrF_2$ with "Freon-14"	2402	93.6 6.4	83.3 16.7	200	460	565	605	3.6
$CBrF_2CBrF_2$ with nitrogen	2402	99.8 0.2	98.1 1.9	200	265	305	320	0.6
$CBrF_2CBrF_2$ with nitrogen	2402	99.6 0.4	96 4	400	520	585	605	1.2

*See explanation of Halon No. in footnote, Table I, page 112.

**Container liquid full at 150°F for $CBrF_2CBrF_2$ and CBr_2F_2 mixtures; at 115°F for $CBrF_3$ mixtures.

3. There should be enough excess propellent so that brief discharge while inverted (loss of of vapor) will not depressurize the system.

4. The propellent should not excessively dilute the extinguishing fluid.

5. The system must develop only moderate pressure at high ambient temperatures.

There are only a few non-toxic, non-flammable propellents which will produce the required pressure at so low a temperature (minus 65°F). Nitrogen and carbon tetrafluoride ("Freon 14") were chosen as the most likely candidates. CBr_2F_2 (Halon 1202), $CBrF_3$ (Halon 1301) and $CBrF_2CBrF_2$ (Halon 2402) were pressurized with these propellents and the relation of composition to pressure at various temperatures determined. These data are shown in Table VIII.

An examination of the pressure changes with temperature indicates that the pressure change in mixtures containing nitrogen is appreciably less than for mixtures containing carbon tetrafluoride. From this standpoint, pressurizing these extinguishing agents with nitrogen should be more satisfactory than with the fluorinated propellent. On the other hand, mixtures with the same pressure at minus 65°F contain several times as much carbon tetrafluoride as nitrogen and as a result more uniform pressure is maintained throughout the liquid discharge of such a mixture.

The last column of Table VIII shows the relative amount of propellent present, assuming that it is all in the vapor phase. For example, in a cylinder containing nitrogen and CBr_2F_2 (Halon 1202) at a pressure of 200 psig there is only enough nitrogen present originally to fill the cylinder 0.7 full when the pressure is set at 100 psig. Under the same circumstances, there is enough carbon tetrafluoride present to fill the cylinder three times. The effect of the different amounts of propellent on the pressure during liquid discharge of a cylinder is shown on Figure 1. These curves are calculated for $CBrF_2CBrF_2$ (Halon 2402) assuming that the container is originally liquid full at 150°F but it is discharged at minus 65°F. If the vapor space in the cylinder were greater the shape of the curves would be similar but they would be closer together.

Examination of the curves in Figure 1 leads to the following observations:

1. The pressure falls rapidly in the early stages of the discharge with nitrogen as the pro-

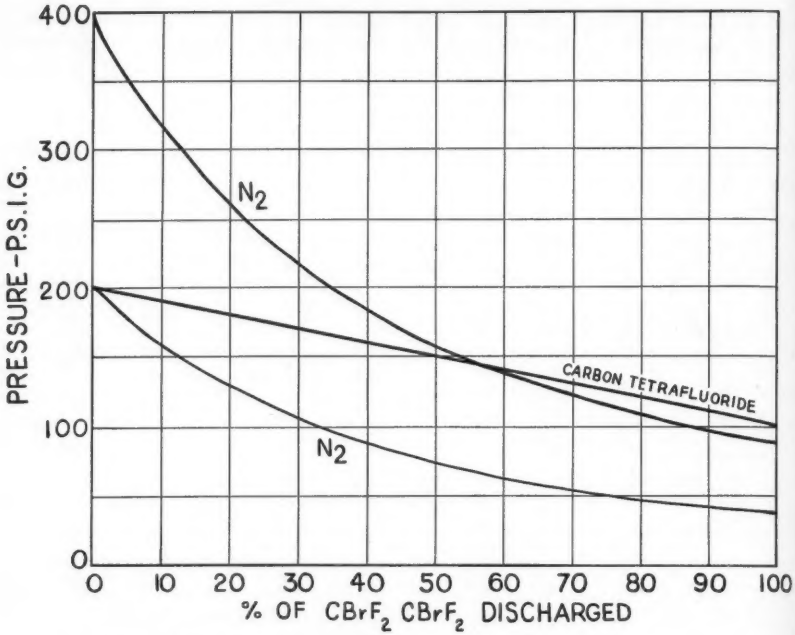


Figure 1. Liquid phase discharge of dibromotetrafluoroethane at –65°F., with carbon tetrafluoride and nitrogen propellants.

pellent and slowly with carbon tetrafluoride.

2. Toward the end of the discharge the pressure is much greater with carbon tetrafluoride than with nitrogen, when starting with the same initial pressure.

3. With nitrogen, the final pressure falls to one-fifth of the starting pressure while with carbon tetrafluoride, the pressure at the end of the discharge is one-half of the initial pressure.

The curves in Figure 1 were calculated assuming equilibrium between the liquid and gas phases in the cylinder throughout the discharge.

In pressurizing fire extinguishing fluids it is not desirable for the propellent to be too soluble in the liquid since in this case an excessive amount of propellent is required to produce the specified pressure. This point is well illustrated by the pressurized compounds shown in Table IX.

TABLE IX

Pressurized Extinguishing Agent Mixtures Showing deviation from Raoult's Law*

Research by the Jackson Laboratory

Mixture	Halon No.**	Weight Percent Liquid Phase	Vapor Pressure at minus 65°F psia Calculated	Vapor Pressure at minus 65°F psia Observed
CBr_2F_2	1202	95.0	47	215
Carbon tetrafluoride		5.0		
$CBrF_2CBrF_2$	2402	93.6	70	215
Carbon tetrafluoride		6.4		
$CBrF_3$	1301	68.	196	215
Carbon tetrafluoride		32.		
CBr_2F_2	1202	99.8	...	215
Nitrogen		0.2		

*Raoult's law: the vapor pressure of the solvent in equilibrium with a solution is directly proportional to its mole fraction in that solution.

**For explanation, see page 112.

The vapor pressure of a mixture of liquids can be calculated by Raoult's Law and, in most cases, this value is reasonably close to the observed value.

In Table IX the calculated pressure is compared with the observed pressure for mixtures with carbon tetrafluoride. For $CBrF_3$ (Halon 1301), the two values are similar and a considerable amount of the propellent was needed to raise the pressure to 215 psia. With $CBrClF_2$ (Halon 1202) and $CBrF_2CBrF_2$ (Halon 2402) the measured pressure was far higher than the calculated value showing an exceptionally large deviation from Raoult's Law and only a moderate amount of propellent was needed. These mixtures are compared with nitrogen which has very low solubility in these compounds so only a very small amount is needed to increase the pressure.

In comparing carbon tetrafluoride with nitrogen as pressurizing materials we find that the pressure change with temperature is less with nitrogen and that less of it is needed to produce the same initial pressure. With carbon tetrafluoride, the pressure is more uniform during the liquid discharge of a cylinder and the final pressure relative to the initial pressure is higher than with nitrogen.

Part II
Research at the Corps of Engineers' Laboratories†

By J. E. Malcolm
Project Engineer, Fire Fighting Equipment Section

This discussion concerns the research and development work on new vaporizing liquid fire extinguishing agents conducted at and under the auspices of the Engineer Research and Development Laboratories, located at The Engineer Center, Fort Belvoir, Virginia. Acknowledgment is made to the Air Development Force of the USAF* for participation in the program.

The project was undertaken with the following objective: *"Development of an improved, self-contained fire extinguishing agent to replace existing agents used in combating Class 'B' flammable liquid and Class 'C' electrical equipment fires."* The project was initiated after our Laboratories conducted preliminary evaluations of the German fire extinguishing agent, chlorobromomethane, in August 1946.*

Since the first tests indicated superior effectiveness of chlorobromomethane as compared to carbon tetrachloride, it was decided to undertake a survey of the entire vaporizing liquid field. In the examination of the data which are to be presented it will be noted that most of the compounds investigated are halocarbons or halohydrocarbons, that is; chemical agents formed from the elements of carbon and one or more of the following: fluorine, chlorine, bromine, iodine and, theoretically, astatine; and, in the case of halo-

†The Engineer Research and Development Laboratories conduct research and development as required on Corps of Engineers' equipment and techniques of operation. In the Army, the Corps of Engineers is responsible for providing fire fighting equipment and personnel, both in camps, posts and stations and in combat zone installations. In addition to the Army requirements, the Corps of Engineers is responsible for the supply of fire fighting equipment for use in ground installations of the Air Force.

*See April 1950 NFPA *Quarterly*.

*See July 1948 NFPA *Quarterly*, page 46.

hydrocarbons, hydrogen atoms are also present in the chemical agent molecule. There are chemical reasons for the predominance of this family of compounds in the number which have been investigated. Carbon forms stable compounds with the halogen elements. These compounds are volatile; they are non-conductors of electricity; they do not undergo rapid reactions with water or become electrically conductive in the presence of water and, where the weight of the halogen components of the individual molecules predominate, the compounds are nonflammable.

Editor's Note: The statement regarding the nonflammable property of these compounds contemplates normal conditions of use. At elevated temperatures (1000°F. or over), and under certain conditions of application, most of these compounds have been found to have an autogenous ignition temperature. The significance of this fact as related to their use in practical fire extinguishment has not been completely evaluated.

Purposes of Research

The Engineer Research and Development Laboratories contracted with the Purdue Research Foundation to carry out the necessary Laboratory studies and investigations of vaporizing liquids looking toward the development of an improved agent. In setting up the research program, the following requirements were established:

GENERAL REQUIREMENT: The agent shall be suitable for use on both Class "B" and "C" fires.

SPECIFIC REQUIREMENTS: The agent shall be: (1) Less toxic than carbon tetrachloride; (2) less corrosive than carbon tetrachloride; (3) a nonconductor of electricity; (4) stable when stored for five years in any climate, and (5) suitable for use at atmospheric temperatures from minus 65 degrees F. to plus 160 degrees F.

Basic Test Procedure

The Purdue Research Foundation established a test procedure that would render reproducible results, be applicable to a number of different compounds, require only a small amount of compound to be evaluated, and be conveniently operated. This was the same procedure used by the Bureau of Mines* to investigate flammable limits of various fuels and the effect of certain inert gases on these limits was adopted. The method evaluates the flame inhibition properties of inert gases or vapor, on mixtures of a combustible vapor and air, and consists of determining whether or not a given mixture of the three components can be ignited by a spark gap. For a given agent a number of determinations are made with varying mixtures, and the instances of flame propagation or nonpropa-

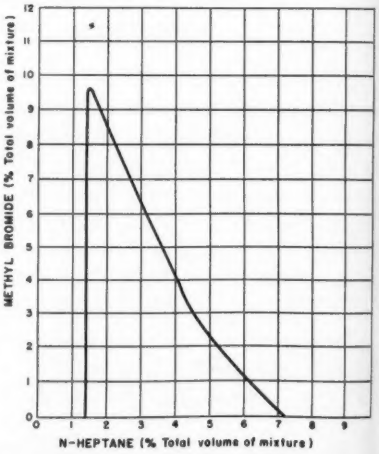


Figure 2. Flammability curve for methyl bromide (Halon 1001) in a mixture of n-heptane and air. Area under curve represents conditions of flammability, above curve, nonflammability.

*H. F. Coward and G. W. Jones, *Limits of Inflammability of Gases and Vapors*, U. S. Department of the Interior, Bureau of Mines, Bulletin 279, Washington, U. S. Government Printing Office, 1939.

gation and the concentrations of the components are recorded.

The data obtained in these tests were expressed graphically, the volume percentage of the agent being plotted against that of the combustible vapor. For example, it can be seen in Figure 2 that a "peak in the flammability" area occurs at 1.4-9.7 per cent in a normal heptane-methyl bromide mixture. This "peak" is *the minimum concentration of agent in the combustible mixture that will inhibit flame propagation for any concentration of the combustible material,* and is consequently taken as a criterion of the effectiveness of the inert vapor in inhibiting flame propagation.

The "flammability peak" criteria may be compared to determine the relative values of various agents on the volume basis. For example methyl bromide (Halon 1001) with a "flammability peak" at 9.7 per cent in n-heptane and air is superior, volume for volume, to carbon dioxide with a "flammability peak" at 29.5 per cent under the same condition; that is, the *volume of methyl bromide vapor required to inhibit flame propagation in a given volume of combustible gas mixture would be one-third that required if carbon dioxide were used.*

The laboratory flame extinction and inhibition data were collected on a vapor volume basis because it was the most convenient method. However, to provide a means of evaluating the agents on a practical basis, it was necessary to express their extinguishment effectiveness in terms of a percentage based on the weight of the agent. For this purpose the following formula was used (methyl bromide is taken as the criterion, since one goal of the project was to develop an agent superior to it in effectiveness):

$$E = \frac{V_a M_a}{V_a M_a} \quad (100)$$

Where E = Percentage weight effectiveness (methyl bromide being 100%)

V_b = Volume percent of methyl bromide at its "flammability peak" with n-heptane as the fuel

V_a = Volume percent of agent at its "flammability peak" with n-heptane as the fuel

M_b = Formula weight of methyl bromide

M_a = Formula weight of agent

A selection of the test results obtained in the laboratory investigations conducted at the Purdue Research Foundation is presented in Table X. Of primary practical interest, is the weight effectiveness of the various agents, which were calculated from the laboratory data based on a 100 per cent effectiveness for methyl bromide (Halon 1001). It is noted that no great increment over 100 per cent effectiveness was found for any of the agents except for hydrogen bromide and ethyl bromide (Halon 2001). Practical fire tests employing ethyl bromide showed erratic performance and inferior effectiveness for this compound as compared to methyl bromide. It is of interest in the case of these two compounds, methyl and ethyl bromide, that they will support combustion in certain narrow concentration limits, as recorded in chemical literature.

In these data, dibromodifluoromethane (Halon 1202) is indicated to have a slight advantage over bromotrifluoromethane (Halon 1301). This fact is borne out in most of the normal temperature fire tests.

Of theoretical interest are the calculated concentrations of agents at the "flammability peaks." These calculated values are computed, based on the following apparent atomic values of fire-fighting effectiveness for the halogens when chemically combined: fluorine 1; chlorine 2; bromine 10, and iodine 16.

These values were deduced upon examination of the test data and correlation with chemical structures of the compounds tested. The weight values of the above halogens resolve to the following approximations when the atomic weights of the respective elements are considered: fluorine and chlorine: 1; bromine and iodine: 2.

TABLE X

Selected Results from Laboratory Studies Conducted at Purdue Research Foundation for the Engineer Development and Research Laboratories

Agent	Chemical Formula	Halon Number*	Calculated Conc. of agent at "flammability peak" with n-heptane	Observed Conc. of agent at "flammability peak" with n-heptane	Weight effectiveness Percent (Methyl bromide = 100)
Dibromodifluoromethane	CBr_2F_2	1202	4.5	4.2	107
1,2-dibromo-1,1-difluoroethane	CF_2BrCH_2Br	2202	4.3	4.3	95
Tribromofluoromethane	CBr_3F	1103	3.2	4.3	81
1,2-dibromo-2-chlorotrifluoroethane	$CF_2BrCFClBr$	2312	4.0	4.6	73
2-bromo-1,1,1-trifluoropropane	$CF_3CHBrCH_3$	3301	7.7	4.9	106
1,2-dibromotetrafluoroethane	$CBrF_2CBrF_2$	2402	4.2	4.9	72
Methylene bromide	CH_2Br_2	1002	5.0	5.2	102
Ethyl iodide	CH_3CH_2I	20001	6.2	5.6	105
Bromopentafluoroethane	CF_3CF_2Br	2501	6.6	6.1	76
Methyl iodide	CH_3I	10001	6.2	6.1	106
Bromotrifluoromethane	$CBrF_3$	1301	7.7	6.1	101
Ethyl bromide	C_2H_5Br	2001	10	6.2	136
Perfluoromethylcyclohexane	$C_6F_{11}CF_3$	....	7.1	7.5	35
Perfluoroheptane	C_7F_{16}	....	6.2	7.5	32
Chlorobromomethane	CH_2BrCl	1011	8.3	7.6	94
Bromochlorodifluoromethane	$CBrClF_2$	1211	7.2	9.3	60
Hydrogen bromide	HBr	....	10	9.3	122
Methyl bromide	CH_3Br	1001	10	9.7	100
Perfluorobutane	C_4F_{10}	....	10	9.8	39
Silicon tetrachloride	$SiCl_4$	....	12.5	9.9	55
Carbon tetrachloride	CCl_4	104	12.5	11.5	52
Chlorotrifluoromethane	$CClF_3$	131	20	12.3	71
Dichlorodifluoromethane	CCl_2F_2	122	16.8	14.9	51
Sulfur hexafluoride	SF_6	....	16.8	20.5	31
Carbon dioxide	CO_2	....	....	29.5	71
Boron trifluoride	BF_3	....	33	20.5	66
Phosphorus trichloride	PCl_3	....	16.8	22.5	30
Carbon tetrafluoride	CF_4	14	25	26	40

*For explanation of Halon No., see page 112.

It is noted that the above method for estimating the concentration of agent at the "flammability peak" is not precise in that no adjustment or allowance is made for the fact that the oxygen concentration is critically reduced at high concentrations of agent (for agents of high flammability peaks).

The trend noted is of theoretical interest as well as the apparent relative values for combined bromine and chlorine in flame inhibition. An attempt will be made to use these general observations in the ultimate explanation of the mechanisms involved in flame extinguishment.

Over 60 different compounds were evaluated by the flame inhibition method at the Purdue Research Foundation. It was realized, however, that the flame inhibition method of screening compounds with respect to fire extinguishing effectiveness was open to some question, *i.e.*, from the flame inhibition tests at agent concentrations where no flame was propagated, it could not be safely assumed that the given agent concentrations could extinguish a flame which had been initiated before application of the agent.

To remove the doubt concerning the interpretation of the data, a series of tests were made by the Engineer Research and

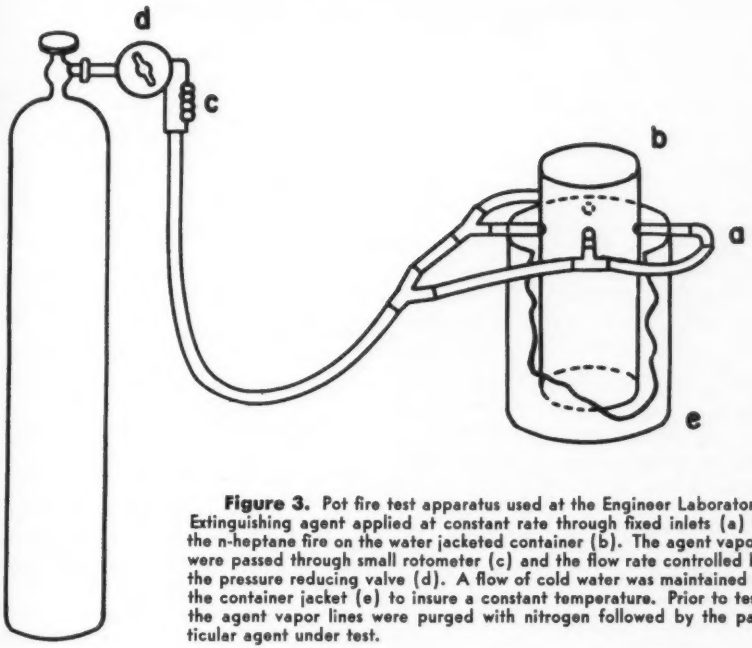


Figure 3. Pot fire test apparatus used at the Engineer Laboratory. Extinguishing agent applied at constant rate through fixed inlets (a) to the n-heptane fire on the water jacketed container (b). The agent vapors were passed through small rotometer (c) and the flow rate controlled by the pressure reducing valve (d). A flow of cold water was maintained in the container jacket (e) to insure a constant temperature. Prior to test, the agent vapor lines were purged with nitrogen followed by the particular agent under test.

Development Laboratories in which inert vapors (various halogen compounds and carbon dioxide) were applied to small n-heptane fires under closely controlled conditions. These tests were not designed to check the "flammability peak" data of individual compounds tested at Purdue, but to determine if the relative effectiveness of various agents as indicated by the flame inhibition method was valid for the agents when applied to the n-heptane pot fires in the laboratory.

Figure 3 shows and describes the test apparatus. The container was filled with n-heptane to within exactly one inch of the fixed inlets. After the heptane had been ignited with gas burner, a preburn of 30 seconds was permitted, following which, the agent vapors were admitted to the test container at a predetermined and constant pressure (constant flow rate), and the time of extinguishment was noted by a stop watch. Finally, the jacketed container, which was located under a laboratory hood, was flushed with fresh air. The amount of agent required could be calculated from the time and rate of flow, and various rates were used to determine if this variable affected the results significantly. This method was adaptable only to compounds which are gases at room temperature and pressure.

Although the goal of this project was to develop, if possible, a *single* agent that would meet all the military requirements, the Purdue Research Foundation noted that there was a possibility that a *mixture*

TABLE XI

Effect of Various Combustibles on Flammability of Mixtures
Research by Engineer Laboratories

Combustible	Chemical Formula	Concentration of Agent at Flammability Peak (% by Vol.) CH_2Br_2 (Halon 1002)	$CBrF_3$ (Halon 1301)	C_2H_5Br (Halon 2001)	CH_3Br (Halon 1001)	SF_6	CF_4 (Halon 14)
n-heptane	C_7H_{16}	5.2	6.1	6.2	9.7	20.5	26
Isopentane	C_5H_{12}	6.8	6.3	6.3	8.4	19.8	20.4
Benzene	C_6H_6	7.3	4.3	8.2	8.4	18.3	23.6
Ethyl alcohol	C_2H_5OH	5.7	3.7	5.2	6.2	10.6	19.8
Diethyl ether	$(C_2H_5)_2O$	7.7	6.3	7.3	7.2	21.8	22.4
Acetone	$(CH_3)_2CO$	5.7	5.3	5.8	7.3	16.4	18.7
Ethyl acetate	$CH_3CO_2C_2H_5$	4.3	4.6	6.3	6.8	17.5	21.4

of two or more agents would meet the requirements. For this reason, a limited study was conducted to determine fire extinguishing effect of mixtures of two agents. Records were kept whether or not a binary mixture was more effective, as effective or less effective than the molar average effectiveness. The results were such that no distinct advantage could be seen in the mixture of agents.

In the tests of flame inhibition, n-heptane was selected as the combustible, since it is a typical straight chain hydrocarbon and possesses sufficient volatility. To demonstrate, from the standpoint of combustible material, the significance of the tests with n-heptane, a study was made to determine if the relative effectiveness of an agent varied appreciably when applied to different combustibles. The study was carried out by determining the "flammability peaks" of various agents in the combustible vapors of acetone, benzene, diethyl ether, ethyl acetate, ethyl alcohol, and isopentane.

The test data for flame inhibition tests conducted on various fuels are shown in Table XI. It is shown that essentially the same order of effectiveness between the various agents held for all the fuels evaluated.

The bulk of the flame inhibition tests were carried out at room temperature; however, since an agent was desired which would be effective over a wide temperature range, a series of tests were made to determine the "flammability peak" at −78°C, 27°C, and 145°C (−108°F, 81°F, and 293°F respectively) so that any temperature effect might be noted. These temperatures were selected for experimental convenience, and isobutane was selected as the combustible, since it possessed better volatility at reduced temperatures than n-heptane.

The results of the low temperature tests are presented here in Table XII. A slight

TABLE XII

Summary of Results of Low Temperature Tests
Research by Engineer Research and Development Laboratories

Agent	Halon No.	Avg. Ext. Time (Sec)	Avg. Wt. Agent to Ext. (Oz)	No. Valid Tests	No. Ext.	Temp. Range (Deg. F)
Mist Application (400 psig)[a]						
Methyl bromide	1001	7.6	33.5	12	6	−56 to −64
Dibromodifluoromethane	1202	6.6	24.5	11	11	−55 to −65
Bromotrifluoromethane	1301	3.0	21.0	16	14	−50 to −60
Dibromotetrafluoroethane	2402	5.5	24.0	10	3	−51 to −58
Straight Stream Application (200 psig)[a]						
Methyl bromide[b]	1001	3.5	27.0	3	1	−56 to −57
Dibromodifluoromethane[b]	1202	4.0	26.0	1	1	−59 to −60
Dibromotetrafluoroethane[b]	2402	3.0	22.5	1	1	−54 to −55

[a] Extinguisher cylinders were pressurized to the indicated pressure at 70°F with N_2.

[b] Agents naturally liquid at room temperature; commercial carbon tetrachloride nozzle used for application.

TABLE XIII

Effect of Temperature on the "Flammability Peak" of Compounds with Isobutane (C_4H_{10})
Research by Engineer Laboratories

Fire Ext. Agent	Formula	Halon No.	Concentration at Peak Flammability (% by Vol.) at −78°C		at +27°C		at +145°C	
			Agent	C_4H_{10}	Agent	C_4H_{10}	Agent	C_4H_{10}
Bromotrifluoromethane	$CBrF_3$	1301	3.25	4.5	4.7	4.6	7.3	4.0
Methyl bromide	CH_3Br	1001	3.75	3.5	6.75	4.0	8.3	4.0
Chlorotrifluoromethane	$CClF_3$	131	8.25[a]	3.5	10.75	4.25	12.8	4.0
Sulfur hexafluoride	SF_6	....	12.75	5.0	15.75	5.0	17	5.5
Carbon tetrafluoride	CF_4	14	18.25	5.0	23.75	4.0	21.4	3.5

[a] Divided flammable area noted, lower peak at 2.0.

advantage of bromotrifluoromethane over dibromodifluoromethane is noted. The temperature data presented in Table XIII also indicate no change in the relative effectivenesses of the various agents evaluated between −78°C and 145°C.

Stability of Agents

Since the agent would be subject to storage under any climatic conditions for long periods of time in a metal container, stability to metals was chosen as a means of classifying the materials. Preliminary studies at Purdue Research Foundation showed that the compounds being evaluated were, in general, stable to powdered aluminum at reflux temperatures. Accordingly, a series of experiments were conducted in which the test compounds were heated in contact with strips of metal at 392°F (200°C). In general, only the materials boiling above about 50°C were used in this study and these compounds were chosen to show the effects, if any, of structural relationships on instability.

Polished and weighed strips of metal and 20 ml of the halogen compound were sealed in

TABLE XIV

Stability of Halogen Compounds after 30-Day Contact with Metals at 200°F and 392°F
Research by Purdue Research Foundation for Engineer Laboratories

Compound	Weight Change at Indicated Temperatures: Aluminum 392°F	Aluminum 200°F	Brass 392°F	Brass 200°F	Copper 392°F	Copper 200°F	Iron 392°F	Iron 200°F	Magnesium 392°F	Magnesium 200°F
Halocarbons										
Perfluoroheptane	B	..	A	..	A	..	A	..	..	A[a]
Perfluoromethylcyclohexane	B	..	A	..	A	..	A	..	..	A[a]
1,1,2-trichlorotrifluoroethane	A	..	..	..	C	..	A	..	..	B[b]
1,2-dibromotetrafluoroethane	D	A	..	A	C	A	A	A	..	..
1,2-diiodotetrafluoroethane	..	C[b]	..	B[b]	..	..	..	B[b]	..	..
Carbon tetrachloride	B	C	..	B	D	B	B	B	..	..
Halohydrocarbons										
1,-bromo-3,3,3-trifluoropropane	A	..	..	..	B	..	B	..	..	..
2,-bromo-3,3,3-trifluoropropane	D	A	B	A	C	A	B	A	..	..
1,2-dibromo-2,2-difluoropropane	..	A[c]	..	A[c]	..	..	..	B[c]	..	B[c]
1-bromo-2-chloroethane	C	D	..	A	C	B	C	B	..	B
Chlorobromomethane	C	..	..	..	D	..	B	..	..	..
Methylene bromide	C	..	..	..	D	..	C	..	..	..
Ethyl bromide	..	C[d]	..	B[d]	..	..	..	C[d]	..	B[d]
Ethyl iodide	..	C[d]	..	B[d]	..	..	..	C[d]	..	B[d]

Code: A—Weight change less than 0.01 g.
B—Weight change between 0.01 and 0.1 g.
C—Weight change greater than 0.1 g.
D—Completely consumed.

Notes: ([a]) contact time 27 days.
([b]) contact time 14 days.
([c]) contact time 32 days.
([d]) contact time 11-15 days.

(Original weight of all samples varied from 1.2 to 3.5 g, depending on the type metal.)

ampoules (Carius tubes). The weight of the samples varied from 1.2 to 3.5 g, depending on the type of metal. The tubes were inserted in iron pipes which, in turn, were placed in an oven heated at 392°F. After 30 days, the tubes were allowed to cool to room temperature and then opened. The physical appearance of each strip was noted and the liquid contents were stored in vials for future studies. After removing coatings from the strips which had corroded, the strips were reweighed and changes in weight compared with the original value were recorded. This study was initiated to show the stability of halogen compounds to aluminum, copper and iron, common materials of construction. After this study was initiated brass strips were substituted for copper strips.

Compounds showing marked instability to the metals at 392°F, were heated in contact with the same metals at 200°F. In addition, experiments were conducted in which the halogen-containing compounds were heated in contact with magnesium ribbon at 200°F.

A resume of the corrosion data obtained at the Purdue Research Foundation is presented in Table XIV. These data represent accelerated corrosion at elevated temperatures. Corrosion studies are continuing at the Engineer Research and Development Laboratories.

Agents Found Nonconductors

One of the specific requirements of the new type agent is that it be suitable for application to Class C fires; that is, it must be essentially a nonconductor of electricity. In view of this the Purdue Research Foundation undertook appropriate volume resistivity measurements of various halocarbons. These results indicated that the compounds are as anticipated, for practical purposes, nonconductors.

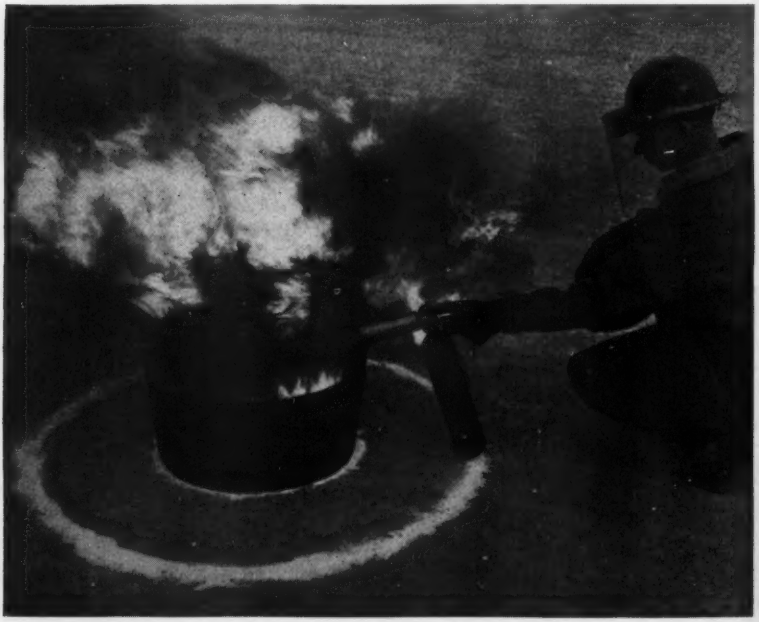


Figure 4. Class B tub fire test at the Engineer Laboratory. The steel tub was 2 ft. in diameter filled with water to within 10½ in. of rim. Two quarts of gasoline were poured on the water and a 20-second preburn was allowed before the fire was attacked as shown.

Figure 5. Cotton waste fire test at the Engineer Laboratory. Test shown is one using four pounds of cotton waste in a 2 by 2 ft. area evenly wetted with one quart of gasoline. Test actually used for the record was more severe; eight pounds of waste in a 2 by 4 ft. area wetted with 2 quarts of gasoline. A 10-second preburn was allowed in all tests before the fire was attacked.

Practical Extinguishment Tests

In order to verify the findings of the laboratory studies, and to make a final screening of the compounds displaying superior fire extinguishing effectiveness, practical tests were conducted on Class B and cotton waste fires with the following agents:

Agent	Halon No.*
Bromotrifluoromethane ($CBrF_3$)	1301
Dibromodifluoromethane (CBr_2F_2)	1202
Dibromotetrafluoroethane ($CBrF_2CBrF_2$)	2402
Perfluoromethylcyclohexane ($C_6F_{11}CF_3$)	....
Methyl bromide (CH_3Br)	1001
Carbon tetrachloride (CCl_4)	104
Carbon dioxide (CO_2)	....
Methyl iodide (CH_3I)	10001
Chlorobromomethane (CH_2BrCl)	1011

*For explanation of Halon No., see page 112.

The first two compounds listed, bromotrifluoromethane (Halon 1301) and dibromodifluoromethane (Halon 1202), were selected because the laboratory studies indicated that the most effective and stable agent would be a bromofluorocarbon having a single carbon atom and at least two fluorine atoms per molecule. The second two compounds represent intermediate degrees of effectiveness among new agents studied in the laboratory at the Purdue Research Foundation, while the remaining chemicals either represent existing standards or have been proposed in the past as fire extinguishing agents, and have been tested in the studies conducted at the Purdue Research Foundation. The results are given in Table XV on the following page.

TABLE XV

Weight Effectiveness, in Percentage, of Selected Agents Against Class B and Cotton Waste Fires (Average of 10 Tests Unless Otherwise Noted)

Research by Engineer Research and Development Laboratories

Agent	Formula	Halon No.	Class B 24-in. Tub Fire (Agent at 800 psig Initial Discharge Pressure)[a] To Extinguish Avg. Wt. Agent (Oz)	Avg. Time (Sec)	Weight Effectiveness[b] (%)	Class B 24-in. Tub Fire (Agent at 400 psig Initial Discharge Pressure)[a] To Extinguish Avg. Wt. Agent (Oz)	Avg. Time (Sec)	Weight Effectiveness[b] (%)	2- by 4-ft Cotton Waste Fire (Agent at 400 psig Initial Discharge Pressure)[a] To Extinguish Avg. Wt. Agent (Oz)	Avg. Time (Sec)	Weight Effectiveness[b] (%)
Dibromodifluoromethane	CF_2Br_2	1202	7.6	1.9	148	6.6	1.4	120	20	5.7	100
Bromotrifluoromethane	$CBrF_3$	1301	7.7	3	146	7.6[c]	3[c]	105[c]	15.6	6.7	126
Carbon dioxide	CO_2	....	9.1	5.2	124	9.1	5.2	88	32[g]	..	..
Dibromotetrafluoroethane	$CBrF_2CBrF_2$	2402	10.5	2	107	10.8	2.3	74	19.8[g]	..	..
Dichlorodifluoromethane	CCl_2F_2	122	10.8	3	104	12	4.1	68	(27)[f]	(10)[f]	(74)[f]
Methyl bromide	CH_3Br	1001	11.3	3.4	100	8.0	2.1	100	20	5	100
Ethyl bromide	C_2H_5Br	2001	11.7	2.8	96	(16)[d]	(5.5)[d]	(50)[d]	..	..	..
Methyl iodide	CH_3I	10001	11.7	2.8	96	..	..	..	..	..	..
Chlorobromomethane	CH_2BrCl	1011	12.7	2.7	80	..	..	..	..	..	..
Carbon tetrachloride	CCl_4	104	(15)[d]	(3)[d]	(75)[d]	11.4	2.0	68	32[g]	..	..
Perfluoromethylcyclohexane	$C_6F_{11}CF_3$	....	..	..	..	(24)[e]	(7)[e]	(33)[e]	32[g]	..	..
Bromochlorodifluoromethane	$CBrClF_2$	1211	..	..	..	10.7	2.3	75	..	..	..
1,2-dibromo-1,1-difluoroethane	CF_2BrCH_2Br	2202	..	..	..	12	2.2	66	..	..	..

[Extinguishment times subject to human error in timing short intervals involved.]

[a] Agents were discharged from a 2½-lb. CO_2 extinguisher charged with 2 lbs. of agent, and then pressurized with nitrogen at 70°F. CO_2 discharge pressure in all cases was approximately 800 psig.

[b] Methyl bromide taken as 100%.

[c] Five tests.

[d] Average values for successful extinguishments only. (6 failures in 10 tests.)

[e] See ([d]), above, (3 failures in 5 tests).

[f] See ([d]), above, (2 failures in 5 tests).

[g] Not effective in combatting the fires.

Editor's Note: Readers should note the variances in the rates of discharge of the agents tested [i.e., Halon 1202 discharged at a rate of 4 oz./sec. (7.6 oz. in 1.9 sec.), whereas CO_2 was discharged at a rate of only 1.75 oz./sec. (9.1 oz. in 5.2 sec.)]. These rate of discharge differences make agent for agent comparisons difficult. Entering into this consideration is the question of efficiency with which a practical quantity of agent can be applied to a fire of the incipient type.

Another important factor is range effectiveness. Some of these agents have very little range effectiveness meaning that the application must be at very close range. In all these tests, the agent was applied at very close range (see Figures 4 and 5). The range of the agents naturally depends on their physical state at ambient temperature and the method and apparatus of application. Gases or mists do not have the range of a straight stream, however, such a state of application is generally more effective on most types of incipient class B and C fires.

It should also be noted that Table XV shows no Class "A" fire tests.

Standard Underwriters' Laboratories tests were modified to accommodate 2-pound agent test samples, 2-foot tub fires being used for the Class B tests and 2- by 2-, 2- by 3-, and 2- by 4-foot cotton waste fire tests. A 2½ lb. CO_2 unit was used for applying the agents in the engineering tests, while the fuel used was unleaded industrial naphtha. The test procedures were based on Underwriters' Laboratory standards. The 2½-pound CO_2 extinguisher was selected because of its simplicity of operation, moderate capacity and dependability.

In conducting the fire tests it was desired to obtain comparable data on liquid and gaseous agents applied under nitrogen pressure. The pressures used were 800 psi (roughly equivalent to the vapor pressure of CO_2 at room temperature), and 400 psi (an intermediate pressure sufficient to insure discharge at –65°F). At these pressures the agent was discharged as a light mist. The human element introduced by the manual attack on the fires, combined with such uncontrolled variables as air turbulence, obviously caused some deviations in the results. For most agents 10 tests were made and the results were averaged. In the time of extinguishment reported there may be varying errors, depending on the individual operators.

From practical fire test data shown in Table XV, it is noted that methyl bromide did not perform as effectively at 800 psig initial discharge pressure, as at 400 psig discharge pressure, which accounts for the high effectiveness recorded for the first four agents in the tests at 800 psig initial discharge pressure. The cotton waste fires were more difficult to extinguish than the Class B fires.

Cold Temperature Tests

A series of tests designed to duplicate as nearly as possible arctic environment, was undertaken in the Engineer Research and Development Laboratories Cold Chamber at temperatures ranging from –55 to –65°F to determine if the otherwise qualified agents were suitable for use under such conditions.

Equipment was set up in the test canopy and in a control room located outside the test chamber to provide semi-automatic and remote control of the tests. An oscillating swivel arm was provided to direct the spray from the test cylinder over the entire surface of the 25-in. square burning pan, in which a spark plug and methane bleed line were provided to ignite the fuel. A photo-electric cell (protected against the low temperature condition) was provided to record the incidence of fire in the pan. The impulse from the photo-electric cell operated through a time delay relay to activate a motion picture camera covering the fire pan. The time delay relay also activated the solenoid and the oscillating motor, the units that provided for the release of the extinguishing agent and the sweep of the extinguisher over the burning pan. The rheostat controlled the period of oscillation, which in these tests, was held at 5½ seconds for a complete cycle. The impulse from the photo-electric cell resulting from the extinguishment of the fire was converted by the relay box to the necessary circuit changes to immediately close the extinguisher valve, cease oscillation of the bracket arm, and stop the motion picture camera. An electric clock was synchronized with the relay box so as to indicate the time required for extinguishment. (See Figure 6.)

The results of the cold temperature tests indicated a slight advantage for bromotrifluoromethane (Halon 1301) over dibromodifluoromethane (Halon 1202) and marked superiority over methyl bromide (Halon 1001) and dibromotetrafluoroethane (Halon 2402). (See Table XII.)

Toxicity Tests

An investigation of toxicity with the following objectives was started at the Army Chemical Center in November 1949: (1) to determine the approximate lethal concentrations of selected new agents and of such agents as chlorobromomethane (Halon 1011) and carbon tetrachloride (Halon 104); (2) to conduct a thorough study of the long-term physiological effects of the finally selected agent or agents; and (3) to conduct toxicity tests in the presence of flame to determine the physiological effects of the selected agents under simulated conditions of application. The

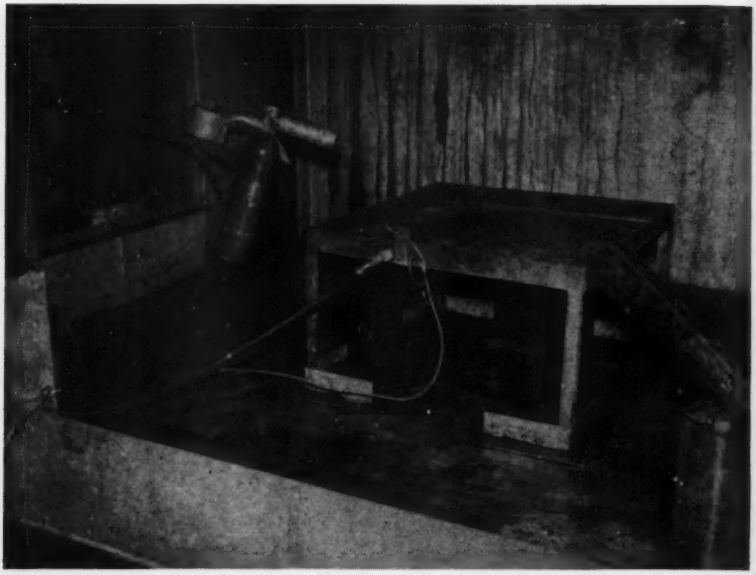


Figure 6. Interior view of low temperature test canopy at the Engineer Laboratory. The assembly was semi-automatically and remotely controlled, the actuation of the extinguisher being mechanical to eliminate the human element. The test canopy used measured 8 by 6¼ by 6½ ft. and was located in a 14 by 13 by 38 ft. cold chamber. The extinguisher used had an aluminum horn for spray applications and a straight stream nozzle for straight stream applications. The table was used to contain test samples.

TABLE XVI

Approximate Lethal Concentrations[a] for 15-minute Exposure to Vapors of Various Fire Extinguishing Compounds

Research by Army Chemical Center

Agent	Formula	Halon No.	Approximate Lethal Concentration Natural Vapor mg/l	ppm	Anesthesia[b] Time min.	Vapor Pyrolyzed in Iron Tube at 800°C mg/l	ppm	Anesthesia Time min.
Bromotrifluoromethane	$CBrF_3$	1301	5075	800,000	1	86	14,000	10
Carbon tetrafluoride	CF_4	14	3220	895,000	2	3220	895,000	2
Bromochlorodifluoromethane	$CBrClF_2$	1211	2200	324,000	4	52	7,650	..
1,2-dibromotetrafluoroethane	$CBrF_2CBrF_2$	2402	1340	126,000	1½	17	1,600	5
Carbon dioxide	CO_2	....	1180	658,000	1	1200	658,000	¼
Perfluoromethylcyclohexane	$C_6F_{11}CF_3$	....	1165	81,000	5	117	7,500	5
Ethyl bromide	C_2H_5Br	2001	660	148,000	5	75	16,500	5
Dibromodifluoromethane	CBr_2F_2	1202	470	54,000	1	16	1,850	3
Chlorobromomethane	CH_2BrCl	1011	340	65,000	1	20	4,000	10
1,2-dibromo-2-chlorotrifluoroethane	$CF_2BrCFClBr$	2312	285	25,000	2	8	700	8
1,2-dibromo-1,1-difluoroethane	CF_2BrCH_2Br	2202	190	20,700	..	110	12,000	..
Carbon tetrachloride	CCl_4	104	180	28,000	..	2	300	..
Methyl bromide	CH_3Br	1001	23	5,900	..	60	9,600	..
Methyl iodide	CH_3I	10001	22	3,800	..	350	60,500	..

[a] Based on tests with white rats by the Medical Laboratories, Army Chemical Center.
[b] At indicated approximate lethal concentration.

detailed planning of this program has been conducted in cooperation with both the Army Environmental Health Laboratory and the Medical Laboratories of the Army Chemical Center.

To date, only screening tests have been completed by the Army Chemical Center. The method used for these tests was adapted from the procedure used by Deichman and Mergard* in their study of approximate lethal doses (ALD) of various compounds. In the tests, white rat specimens were exposed to various vapor concentrations of the agent for a period of fifteen minutes in order to determine the approximate lethal concentration (ALC) of the agent. The ALC is used to indicate the toxicity of the agent when it is inhaled. The term is analogous to ALD, which indicates the toxicity of the agent when it is administered orally or subcutaneously, and is derived in the same manner.

The results of the toxicity testing at the Army Chemical Center are presented in Table XVI. Toxicological evaluations are still in progress on bromotrifluoromethane and dibromodifluoromethane at the Army Chemical Center. In these studies carbon tetrachloride and chlorobromomethane are being used as comparators. Evaluation of all the agents will be conducted with respect to their toxicities when applied to open flames, in other words, toxicities will be determined under conditions of practical application.

*W. B. Deichman and T. J. LeBlanc, *Determination of the Approximate Lethal Dose with about Six Animals*, J. Ind. Hyg., 25 (1943).

Editor's Note: Until toxicity data on practical application tests are available, the information in Table XVI is principally of theoretical value. Note that Halon 104 shows up the worst of all agents when its vapor is pyrolyzed and yet this extinguishing agent is in considerable common usage today.

Currently, service tests are under way using bromotrifluoromethane in an extinguisher specifically designed for its use. In the choice of this particular agent for service test by troops, its effectiveness against Class B and Class C fires, and its low toxicity as compared to the other halogenated agents, were taken into consideration.

Editor's Note: The cost of these halogenated fire extinguishing agents is not covered in this article. Today's cost price of Halons 1202 and 1301 is approximately $3.00-$5.00 per lb. Quantity production might reduce this cost in half or slightly less over a period of time. Halon 1011 ("CB") cost range is somewhere between $.50 and a dollar per pound . The cost of the fluorinated compounds is chiefly influenced by the presence of fluorine. While this chemical gives the agent stability and low toxicity it is not cheap.

Arson Investigation in Selected U.S. Cities

By Kuan-Lou Lee[1]

While the investigation of crimes is customarily a police function, in many local government jurisdictions arson investigation has been made the responsibility of the fire department. It is the purpose of this article to present a brief review of the organization and operation of arson investigation as practiced in selected American cities, with the objective of developing answers to the following questions:

(1) *Should arson investigation be a function of the police department or of the fire department?*

(2) *Can generalizations be made concerning the factors which underlie effective arson investigation taking into account the various types of organizational patterns and the diversity of methods employed in arson investigation?*

These questions are but sides of the same coin, and the answers to one necessitates a due consideration of those of the other.

It should be emphasized, however, that from the time a suspected arson case is reported, until the person accused is acquitted or convicted and the case processed through the judicial hierarchy, the police and fire departments are not the only governmental agencies concerned with arson cases.[2] Under legislation enacted by most of the states, two major responsibilities have been assigned to the state fire marshal, namely, fire prevention and fire investigation.[3] In many jurisdictions, authority for the inspection work carried out by the local fire department is derived from powers conferred by law upon the state fire marshal. As the result of delegation of part of the state fire marshals' power to local fire officials, the chief of a municipal fire department is usually an ex-officio Deputy State Fire Marshal. Except in one of the seventeen key cities, the state fire marshals do not investigate fires within these cities unless requested by the local fire authority. However, the law does reserve the right of the state fire marshal to "supervise and direct such investigation whenever he deems it expedient or necessary."[4] An exception to this policy occurs in some states, however, where it is either common practice or legally required for the state fire marshal to be notified whenever the cause of origin of a fire is not at once established by the local fire official responding to the alarm.

Existing fire records indicate that the trend of arson commitment fluctuates with

[1] Mr. Lee prepared a thesis on this subject in partial fulfillment of requirements for the degree of Master of Science in Public Administration at the University of Southern California. This article reports his essential findings. The text printed here appeared in substantially the same form in *The American Journal of Police Science*, July-August and September-October 1951 issues. The opinions expressed are those of the author.

[2] See listing of public agencies responsible for prosecution of a felony in text "Municipal Police Administration," published by the International City Managers' Association, Chicago, Ill.

[3] The activities of the state fire marshal's office of the State of California are largely confined to "fire prevention work, to foster, promote and develop ways and means of protecting life and property against fire and panic."

[4] Laws of Ohio, Section 824.

business and economic changes.[5] Since industrial and business establishments are, for the most part, concentrated in the large metropolitan areas, the rate of incendiarism reflects business conditions more readily in larger cities. Therefore, the following cities have been selected for study, cities which are geographically scattered throughout the country and which may be considered representative of the entire group of cities whose population exceeds 300,000 persons.

Table I

Cities Selected for Investigation

City	Population[6]
Atlanta, Georgia	326,962
Boston, Massachusetts	788,552
Chicago, Illinois	3,631,825
Cincinnati, Ohio	499,749
Dallas, Texas	432,805
Denver, Colorado	322,412
Detroit, Michigan	1,837,610
Los Angeles, California	1,954,036
Minneapolis, Minnesota	517,410
New Orleans, Louisiana	568,407
New York, New York	7,841,610
Philadelphia, Pennsylvania	1,931,334
San Francisco, California	760,439
Seattle, Washington	462,981
St. Louis, Missouri	852,253
St. Paul, Minnesota	310,155
Washington, D. C.	792,234

Another influence in the rate of arson fires is evident in the emotional stresses of the times (particularly among young people). Pyromania during the current period of world unrest (similar to rising tide of other criminal acts) requires serious consideration in both large and small communities.

Arson Squad Organization

The organization or unit responsible for arson investigation in these seventeen key cities may be classified into four different groups. The arson unit may exist (1) in the fire department, (2) in the police department, (3) as a fire-police combined squad, and (4) in the corporation counsel. The details are listed and explained in Table II.

Among these four groups, there are two different types of organization: (1) that which has a specific arson unit or squad; and (2) that in which arson investigation is carried on by any officer-grade member of the fire or police department. The former type of organization deals with arson investigation exclusively, while the latter type merely performs fire investigation as a part-time responsibility in addition to a wide range of other duties.

As Table II shows, the unit responsible for arson investigation exists in the fire department in thirteen out of these seventeen key cities, two of them in the police department, one police-fire combined squad, and one in the corporation counsel. Under the last mentioned arrangement, the investigators of the arson squad are the police and fire officers detailed to the squad and serving under the command of a lawyer on the staff of the corporation counsel. In only seven out of these seventeen cities have there been organized specific squads dealing solely with arson investigation; in the rest of them, arson investigation is but one among a group routine activities carried out by the fire prevention or the detective division.

With few exceptions, it is a general practice in those cities surveyed that if the arson squad is located within the police department, the detective unit assumes charge of its activities; on the other hand, if it is found in the municipal fire

[5] *Municipal Fire Administration* (Chicago: International City Managers' Association, 1946), p. 28.

[6] These figures are taken from the United States Census Bureau's report, July, 1950.

Table II

Organization of Arson Squads in Selected Cities

City	Fire Dept.	Police Dept.	Fire-Police Combined Squad	Corporation Counsel	Number of Investigators
Atlanta	†	..	..	..	3
Boston	*	..	..	..	7
Chicago	..	..	..	*	5
Cincinnati	†	..	..	..	3
Dallas	†	..	..	..	2
Denver	†	..	..	..	2
Detroit	..	..	*	..	12
Los Angeles	*	..	..	..	10
Minneapolis	*	..	..	..	4
New Orleans	..	†	..	..	All detectives
New York	†	..	..	..	36
Philadelphia	†	..	..	..	6
San Francisco	*	..	..	..	6
Seattle	†	..	..	..	2
St. Louis	..	*	..	..	4
St. Paul	†	..	..	..	2
Washington	†	..	..	..	35

*Specific unit or personnel dealing with arson exclusively.

†No specific squad particularly set up or personnel assigned for arson investigation exclusively; such unit concerned performs a wide range of duties besides arson investigation.

department, the squad is placed under the control of the fire prevention division. The seven arson squads listed above as being organized for specific purpose are operated on a twenty-four hour basis so that they can take action at any time of the day or night.

The officers responsible for arson investigation are usually taken from the regular or uniformed force and assigned to their special duties by department head upon the recommendation of the chief of the division or bureau within the department which is responsible for arson investigation. In most cities the departmental rules and regulations provide that officers selected for arson work can be returned to their regular departmental duties at the discretion of the appointing authority!

Training of Arson Investigators

The difficulties attendant to the selection of persons possessing the unique combination of training, experience, and personal qualifications required for successful arson investigation has been clearly stated in the International City Managers' Association's book entitled "Municipal Fire Administration."[1] The qualifications established for the position of arson investigator should differ from those specified for policemen or firemen and should be more stringent.

The importance of possession of special knowledge for the satisfactory performance of arson investigation has not been generally appreciated and emphasized, and the special training programs for arson investigators have not been developed and conducted until recent years in an orderly and systematic fashion. The majority of the cities studied make no effort to recruit arson investigation personnel possessing special qualifications, but merely secure officers who have been selected from regular duties on the force.

Today, however, there appears to be a trend toward setting up definite qualifications for the recruitment of arson investigators. Cincinnati and Philadelphia

[1] Three qualifications have been advocated by this book: "Firstly, he should be a fire protection engineer . . . with fire fighting experience. . . . Secondly, he should have the talents of a good detective.... Thirdly, he should have legal training and experience as a trial lawyer. . . ."

have done so, and Minneapolis is moving in this direction. On the state level, more attention has been paid to the processes of such recruitment and selection than on the local level. The Commonwealth of Massachusetts has taken the lead in this respect, and requirements for police detective inspector in the division of fire prevention of the state department of public safety have been set up and entrance examinations have been given since about 1933.[3] While the emphasis in this state is heavier on police training rather than on fire investigation, a number of other state fire marshals' offices have adopted the examination policies of Massachusetts. In 1949 the Arson Department of the National Board of Fire Underwriters assisted the Fire Marshal of Ohio in the preparation of examination questions for arson investigators and deputy fire marshals. By and large, the qualifications established for the position of arson investigator in the various state fire marshals' offices may be grouped under four general headings:

GENERAL EDUCATION. High school graduates possessing special training in engineering, chemistry or law courses are preferred.

EXPERIENCE. A specified number of years experience (in Massachusetts, three) in fire investigation work or experience in the conduct of criminal investigation.

SPECIAL KNOWLEDGE. A thorough knowledge of fire prevention laws and ordinances, of rules and regulations issued by the office of fire marshal is usually required.

PHYSICAL REQUIREMENTS AND AGE LIMITS. Physical requirements, for the most part, are based on the same requirements as those specified for the regular policemen or firemen, although usually not as rigorously enforced. Age qualifications are modified to permit the experience requirements.

[3] Fire Marshals' Section, *Year Book and Proceedings of Annual Meeting*, 1933, p. 19; National Fire Protection Association.

Salary Scales

The salary scale for the arson investigators in these seventeen key cities (at the time of this investigation, 1950) ranged from $3,200 to $5,699 per year, the average compensation being around $4,000. In cities, arson investigators were generally not as well paid as investigators employed by State Fire Marshal offices in same geographical area. This difference in compensation constitutes, perhaps, a factor detrimental to the efficiency and morale of the arson investigators serving in some city departments. Actually, the arson investigators in most of these cities are merely experienced firemen or policemen who draw the top salary in their wage classification bracket, and who are detailed or assigned to this particular job. Unless a special classification is designated for such service, there seems to be little hope of raising the salary scale (other than for cost of living) or of securing better qualified personnel.

It is believed that an arson investigator should not be asked to take less than the minimum salary of the lowest grade officer in the department plus his expenses of operation and subsistance when away from his home. An executive in an insurance company investigative office recently declared: "The success of an arson investigation is dependent upon the quality of the personnel who conduct the investigation; when arson investigation is poorly conducted, it would be well to consider the advisability of paying better salaries and employing men who are properly qualified to do the work."

Training and Education

In the past, facilities for the exchange of information among the men in the field of arson investigation, and for the systematic pooling of their knowledge and experience

have been meager. During 1945 a short course for the training of arson investigators entitled an "Arson Investigators' Seminar" was developed at Purdue University, Lafayette, Indiana. Since that time, this instruction program has been carried on annually and by 1950, 1,085 persons had attended, persons performing work directly or indirectly related to arson investigation and drawn from all parts of the country and from abroad. This program places special emphasis upon the technical problems and the procedures of arson investigation which are of the utmost importance to the investigators on the job. The main objectives of the seminar, according to Professor J. L. Lingo, Director of the Public Safety Institute of Purdue University, are "to promote higher standards for the selection and training of persons engaged in the field of arson investigation and to develop more effective and uniform methods and techniques which can be used in the investigation of arson and kindred crimes."[9]

Of the six annual seminars which have been held since 1945, the distribution of attendance by type of organization represented is shown in Table III:[10] This distribution indicates one interesting fact, namely, that at the local level, the ratio of persons from city fire departments in attendance to those from police departments is approximately 4 to 1.

The only other forums on arson investigation methods, techniques and results available to all interested are the semi-annual meetings of the Fire Marshals' Section of the National Fire Protection Association. The work of this group represents an international effort to increase the effectiveness of state and city fire marshals and its continued services are vitally needed.

Table III

Attendants at Purdue Arson Seminars[10]

City Fire Departments	425
State Fire Marshals' Offices	169
City Police Departments	89
Insurance Companies	77
Fire Investigation Organizations	71
State Police	65
Federal Agencies	43
Industries	33
Arson Squads	14
State Crime Laboratories	3
County Police Departments	1
County Sheriffs Departments	1
Others	94
Total	1085

Arson Investigative Methods

With regard to investigative methods, there are two general sets of procedures employed in initiating an arson investigation.

First, the unit responsible for arson work may begin an investigation acting upon an order issued by the chief in response to a fire report upon which a notation of "suspicious origin" or "cause undetermined" has been made. In other words, unless the fire seemed to be of suspicious origin or of a questionable nature in the opinion of the company officer who responded to the alarm, no action will be taken. Therefore, the responsibility for detecting arson in such cases rests almost entirely upon the regular fire officer present at the scene of the fire.

Second, the arson squad or the responsible officer goes to investigate at once upon the call of the chief responding to a fire if he finds any evidence leading to the belief that the fire is of suspicious origin.

[9] Letter of J. L. Lingo to the writer, June 26, 1950.

[10] These figures are derived from the data furnished by Professor J. L. Lingo of the Public Safety Institute of Purdue University, Lafayette, Indiana.

And even though there is no call from the commanding officer on the fire scene, the arson squad responds to all fires that develop into a second alarm or more, or to each case where someone is injured or killed at a fire.

The first practice is usually followed by those units *not* having a specific arson squad or an officer assigned exclusively for such duties. The second practice has become an operational routine where there is an arson squad.

In connection with the first set of procedures several factors need to be considered. The first one concerns the accuracy of the judgment as to the fire's cause as reported by the fire company. According to the usual established procedures the firemen's first concern upon arrival at the scene of a fire is to rescue endangered persons and to prevent loss of life. Secondly, they seek to extinguish the conflagration. And lastly, the determination of the cause of the fire occupies their attention.

Without in any way detracting from the zeal and bravery with which many firemen perform their tasks, one must recognize that those who possess the training and experience needed to enable them to accurately assess the causes of the larger and more complex fires are indeed few in number. It must also be remembered that certain types of evidence such as fingerprints, footprints, odors, etc., may be diluted or destroyed after a certain length of time due to weather conditions. This possibility should be considered, because if the investigation is delayed until the suspicious fire is reported through customary channels, the opportunities to preserve properly such evidence are greatly diminished. If the determination of the cause of fires is to be left to the fire companies, and if the fire investigation then is to be delayed as the result of office routine, will the fire department still be in a position to do a better job of arson investigation than the police department?

Fundamentally related to the various problems of arson investigation is the ratio of incendiary fires to the total number of fires which occur in the selected cities. An analysis of the causes of store fires which occurred during the fifteen-year period from January, 1930 to April, 1946, made by the National Fire Protection Association indicates that of the total of 6,209 fires, 135 were due to incendiary causes or of suspicious origin, a number constituting approximately 2.15 percent.[11]

Since economic and business conditions of the post-war years have been more prosperous than those of the period covered by this study, it is reasonable to conclude that the percentage of incendiary fires in recent years will be somewhat less. According to available fire records for the year 1949, the ratio of the incendiary fires to total fires which occurred in nine key cities varies from .03 to 1.85 percent.[12] Since each of these cities prepares its statistics based upon a somewhat different frame of reference, the reliability of these figures on incendiary fires is open to serious question. Furthermore, "municipal officials who report they have no incendiary fire problems are for most part fooling themselves; they merely do not make an investigation sufficient enough to show whether or not their fires are of suspicious character. Whenever fires are thoroughly investigated, incendiarism may often be found to constitute the principal fire problem of the city."[13]

[11] National Fire Protection Association, *Must Stores Burn?*, 1946, p. 48.

[12] The following data are based upon the annual reports for 1949 of the fire departments in the cities concerned:

City	Total Fires	Incendiary or Suspicious Fires	Percentage
Atlanta	4,836	73	1.47
Boston	3,812	36	.94
Cincinnati ...	3,230	43	1.31
Detroit	7,101	130	1.82
New York ...	44,407	394	.89
Philadelphia ..	11,430	33	.30
Los Angeles..	12,214	227	1.85
San Francisco.	7,308	39	.55
St. Paul.....	3,719	1	.03

[13] *Municipal Fire Administration*, op. cit., pp. 525-526.

This factor may also explain why the city of Los Angeles reported the highest percentage of the entire group, 1.85, when at the same time maintaining a highly efficient arson bureau. On the other hand, the city of Philadelphia reported its incendiary fires at 0.3 percent yet recorded 6,604 out of a total 11,530 fires as "cause undetermined."[14] These statistics serve to indicate that the Los Angeles law enforcement officials are more investigation conscious.

After examining more than 200 heterogeneous forms used for arson investigation and reviewing the great variety of arson statistics presented in the reports of the selected cities the writer was forced to conclude that today the record systems employed resemble those in use in 1938, when Nolting observed that "there are as many record keeping procedures as there are fire departments."[15] The lack of uniformity of arson records and statistics has made impossible the inter-city comparison of the efficiency of arson investigation.

Investigating the Crime Arson

As mentioned in the foregoing sections, whether arson investigation should be a function of police or of fire departments has been a problem prevailing in the field of criminal investigation. In order to develop a constructive solution for, and to clarify, both in theory and in practice, this existing confusion arising from the jurisdictional controversy on the matter of arson investigation, *first*, it is necessary to explore and to simplify the sequence of the investigative processes pertaining to the crime of arson.

In arson cases, the proof of the fire caused by the willful criminal act, or corpus delecti, and the identity of suspect as the one responsible for the fire are the two major elements which the prosecution must establish.[16] From the standpoint of evidence, a decisive factor to the success or failure of arson prosecution, the sequence of the processes of arson investigation is diagramed in Table IV.

Table IV

Processes of Arson Investigation

Fire		Suspect		Court action
1 Discovery of the cause of fires and recognition of evidence	2 Selection, collection and preservation of evidence	3 Apprehension of the criminal	4 Presentation of evidence to district attorney	5 Legal identification of the suspect on the basis of evidence
Arson detection		Criminal investigation		Prosecution

[14] In the 1949's report of Committee on Incendiarism and Arson of the National Board of Fire Underwriters, the following statement is found: "In the course of an investigation into the conduct of affairs in Philadelphia, indictments have been returned against certain deputy fire marshals and their assistants, eight in all. In the two trials held so far, the defendents have been convicted of extortion or receiving bribes." (ED. NOTE: Since this time a thorough fire dept. reorganization has occurred in this city.)

[15] DeWayne E. Nolting, *A Model Records and Reporting System for Fire Departments* (Chicago: Public Administration Service, 1938), Forward.

[16] William C. Bruan, "Circumstantial Evidence in Arson Cases," *The Journal of Criminal Law and Criminology*, Vol. XLI, No. 3, September-October, 1950, p. 226.

Secondly, the knowledge, techniques and experience necessary to the satisfactory performance of each process of arson investigation have to be taken into consideration.

The determination of the cause of fire requires a wide range of knowledge closely related with the subject of fire prevention as well as fire fighting experience. "No attempt has been made to exhaust the list of possible or even probable natural cause of fire, if indeed there is such a list."[17] However, the basic knowledge on natural or accidental fire causes such as radiated heat, mechanical friction, electricity, chemical reactions and spontaneous ignition is of vital importance to the understanding of causes of fire other than accidental origin. It also gives clues to the gathering of evidence of an incendiary fire. In order to facilitate the prosecution, the processes of gathering evidence, physical or circumstantial, necessitates legal knowledge pertaining to the law of evidence and the techniques of recognizing, collecting and preserving it. It is not expected that the investigator should be a lawyer or an expert in all scientific subjects, but he is expected in every case to know what evidence will be required, what are the legal requirements for it, what the technicians can do to assist him in the solution of his case, and how he should submit evidence in such condition that the maximum amount of information can be obtained from it.[18] The success of apprehension of the criminal depends on the knowledge, techniques and experience of criminal investigation and identification. And, when an arson case comes to the stage of prosecution, it involves the question of legal procedures and the application of law.

Thirdly, after exploring the sequence of the investigative processes in arson cases and determining the qualification required for the performance thereof, one must seek to answer the question "who is better trained and qualified to perform each process of arson investigation?"

There is little doubt that fire fighting and fire prevention are the responsibilities of firemen. With training and experience, firemen while working at the scene of a fire could gather information needed to determine if investigation by the arson unit was warranted.

The purpose of the firemen's observation of the facts at the scene of a fire is twofold. First, it expedites immediate recognition of fires of suspicious origin and also aids in locating evidence of fire causes, so that care can be taken in the use of hose streams to avoid the possibility of destroying potential evidence. Secondly, further investigation by the arson unit is facilitated by this information from the firemen.

The importance of the roles which trained and experienced firemen play does not mean that they can also be trained investigators, but it does mean that they can play a highly important part in detecting arson cases. Since it has long been recognized that criminal investigation and apprehension are the policemen's job, and the prosecution of criminal a duty of district attorney, these points demand no further comment.

However, police duties at fires need be mentioned briefly here. Through modern communication systems, the fire alarm comes in at almost the same time to both fire and police departments. Thus the police in a prowl car may arrive at the fire as quickly as does the fire department. The regulations[19] prescribe that the policeman shall, "when he discovers or has his attention called to a fire requiring an alarm, hasten to the nearest fire signal box or telephone and send in an alarm. After making provisions for the direction of responding fire apparatus to the fire, he shall proceed immediately to the scene of fire."[20] Police departments sometimes assign a precinct

[17] *Judging the Fire Risk* (Chicago: Federation of Mutual Fire Insurance Companies, 1949), p. 4.

[18] Lloyd M. Shupe, *The Recognition, Collection and Preservation of Physical Evidence,* a paper reproduced by the Public Safety Institute of Purdue University, Lafayette, Indiana, 1949.

[19] The contents of police regulations dealing with the handling of fires are very much the same. In this section both San Francisco's and New York's are quoted.

[20] San Francisco's Police Rules and Regulations 413.

chief or a lieutenant responsible for the proper policing of the street in the vicinity of such fires and see that the fire department is not interfered with in its work.[21] This end is achieved through the establishment of fire lines and through the control of traffic so that no unauthorized person or vehicle will be admitted within fire lines. The officer in charge of the fire "shall detail members responding to fire so that police duty will be efficiently performed, that life and property will be protected and the commission of crime prevented."[22] When it is believed the fire is of incendiary origin, the police officer "shall take necesary measures to safeguard evidence, and inform the desk officer for notification to fire marshal and the precinct squad detective on duty to investigate."[23] However, "a member of the (police) force shall not independently enter upon the premise where a fire is in progress for the purpose of seeking evidence of incendiarism or other information concerning the origin or cause of the fire. . . . Such information shall be obtained from the officer of the fire department in charge."[24]

In a report to the annual meeting in 1940, the Arson Committee of the Fire Marshals' Section of the National Fire Protection pointed out that "The average police officer is deficient in the practical aspects of fire techniques . . . and the average firemen or fire officer is deficient in the knowledge of legal procedure." However, on the fireman, to a great extent, will rest the responsibility for performing certain important detection duties without which the trained investigator will always be seriously handicapped. "The responsibility of the firemen, then, is arson detection rather than arson investigation."[25]

It is now clear that neither policeman nor fireman are proficient in every one of the investigative processes employed in arson cases. The determination of whether arson investigation be solely a police function or exclusively a fireman's responsibility does not provide an answer to the basic problem. *Successful arson investigation requires positive cooperation between a municipality's police and fire departments.*

Cooperative Fire and Police Function

Complaints are frequently heard, from law enforcement agencies, concerning the delays and ineffective prosecution of arson cases by the prosecutors and the courts. This difficulty stems largely from a lack of adequate evidence so that even the best prosecutor is frequently unenthusiastic about taking to court a weak or borderline case. Once a Chinese Minister of Justice told me that in his opinion justice cannot be achieved in any country without impartial efforts on the part of law enforcement officials, and the success of the criminal prosecution depends much on the evidence which the law enforcement agencies have gathered and submitted to court.

State fire marshals help, or render technical service to local officials to investigate arson. As practice in the majority of the American cities, the responsibility for arson investigation has been placed on the fire department, due to the fact that the chief of the fire prevention bureau is legally an ex-officio fire marshal in the city. This may be ascribed to the influence of the state fire marshal law.

It must be admitted that there are certain functions in the whole process of arson investigation which the police or fire department personnel may do better than the other, but without full cooperation between these two uniformed forces in the city, the investigation of arson tends to be

[21] San Francisco's Police Rules and Regulations, 185.

[22] Same, 418.

[23] New York Police Rule and Regulation, Article 40, H.

[24] Same, Article 318.

[25] *The Firemen's Responsibility in Arson Detection* (Boston: National Fire Protection Association, 1949), Forward.

incompleted, and the prosecution, ineffective. As Table IV has shown, the relationship between the police and fire departments forms an inseparable link in a course of investigation; if this is broken, so would be the link in the chain of evidence. Police and fire departments each have their place in, and must make their contribution to, arson investigation. Without these cooperative efforts, the protection of life and property will not be sound.

The Arson Committee of the International Association of Chiefs of Police has continually urged "the fullest cooperation between the police and fire departments in the investigation of fire."[26] It also advocates "the establishment of arson squad in all police departments to handle this specialized form of crime."[27] (This recommendation obviously applies to cities rather than towns.) There are reasons behind this advocacy. Without special knowledge and experience, amateur crime detectors cannot cope with the professional criminal of today. Arson might be committed in connection with other crimes, or the arsonist might have a previous police record. Processes of arson investigation, from beginning to end, follow criminal procedures step by step which might take a long period of time, or require a considerable amount of human effort. After service has been rendered in the early part of an investigation of arson, it would be functionally and economically unsound for the fire department to continually engage in criminal investigation. All these indicate that the International Association of Chiefs of Police's position relates to two major essentials of effective arson investigation, namely: (1) the functional fitness of the organization; and (2) the professional specialization of the investigators.

Since from the detection and investigation of the crime of arson until the end of its prosecution, each case is to be taken from the fire and/or police departments to the prosecuting attorney's office, the question may be raised as to whether or not the arrangement of assigning the fire and police officers to the arson squad under the command of a prosecuting attorney as currently practiced by the City of Chicago is a superior type of organization for arson investigation. Every police student would appreciate the importance of securing the cooperation of the prosecuting attorney's office and it can be readily imagined what a chaotic condition would result if the police officer fails to possess legal knowledge required in connection with the investigative duties he is assigned to perform. Should the investigation of arson require the leadership of the prosecuting attorney for its effective performance before the case is materialized, why not the investigation of other crimes? This is hardly true. The location of an arson squad in the prosecuting attorney's office tends to sacrifice the initiative of the fire and police officers because such an arrangement places responsibility for arson investigation in the hands of a layman in order to obtain the somewhat dubious advantage of familiarity with legal knowledge and procedures.

There is another question which remains to be answered: Is the joint arson squad comprised of the fire and the police officers physically located in either one of these two departments a most satisfactory solution as to the organizational problems of arson investigation? Indeed, the joint squad could secure a better cooperation between the police and fire departments in arson investigation, but would the administrative control be a problem in the joint squad?

Under the direction of a police inspector-detective the Detroit joint squad operates smoothly. This joint squad consists of five teams, in each of which a police detective and a fire inspector are assigned; the inspector-detective in charge of the joint squad seeks to maintain a close contact with the City Fire Marshal. The police detec-

[26] Arson Committee Report, International Association of Chiefs of Police, 1947, p. 5.

[27] *Ibid.*

tives and the fire inspectors assigned to the arson squad work harmoniously together and encounter few serious problems of administrative control.

From both the theoretical and practical points of view, the combination of the technical knowledge and the special experience of the police detective and fire inspector provides an opportunity to increase the efficiency of arson investigation. Such an arrangement enhances the strength of law enforcement effort and provides a superior type of organization. The inspector-detective in charge of the Detroit arson squad recently observed: "If we do a good job, it is because of two things alone. We investigate a great many fires and we do not rely on the fire department or fire fighting officers to tell us what fires to investigate, and we get to the scene fast and stay on the case until it is complete."[28]

Among other factors underlying the efficiency of an arson squad as mentioned sporadically previously, the competent personnel, the time factor, and the quality and quantity of the work are most important ones. The importance of competent personnel in arson investigation is only second to that of the adequate arson law. The strength of any organization is simply the aggregate strength of the individuals who compose it. As generally recognized, the competency of the special agents of the Arson Department of the National Board of Fire Underwriters is a major factor in the success of that Department. Law enforcement agencies should devote more efforts to the development of adequate programs for recruitment, selection, and training of arson investigators, which will meet the minimum standards commonly agreed upon. Unless this is done so that a specific classification in the service is set up for arson investigator and an incentive salary scale is offered to attract the competent personnel, there is little hope to improve the quality of arson investigation in the organization concerned.

Another consideration affecting the success of fire investigation work is the time factor. The investigation of a fire cannot wait. It must be started as soon as possible after the alarm. This explains why the work of an arson squad is far more satisfactory than those performed by other units responsible for a wide range of other duties.

The third effective deterrent in the efficiency of an arson squad is the quantity of the investigation. However, the quantity of investigation will have no definite weight in efficiency if competent investigators have been secured. Of course, many fire marshals or law enforcement officials have critical problems, particularly as to manpower, but the work cannot be done effectively until fire investigations extend beyond merely those fires which are thought to be suspicious by the fire fighting officers. The situation in Philadelphia that 6,604 out of her total 11,530 fires in 1949 marked "cause undetermined" reminds us of this point. The value of investigating as many fires as possible is twofold: first, the investigators get wide experience in investigating all kinds of fires, and secondly, the public is thereby made conscious of the presence and activities of the investigators, and this acts as a powerful deterrent to acts of arson.

The above findings concerning the factors underlying effective arson investigation are in accordance with the following statement expressed by A. Bruce Bielaski, Assistant General Manager of the National Board of Fire Underwriters, contained in a letter sent to the writer:

> There are certain features which enter into the efficiency of the investigative work: one, the competency of the

[28] Letter of R. K. Goeriz, Inspector-detective of Detroit Arson Squad, to the writer, September 13, 1950.

investigator; two, the presence or absence of the political influence in prosecutions; three, the energy and capacity of prosecuting attorneys; and four, the different standards prevailing in different states and sections of the country.

Although the second and third points of Bielaski's statement are beyond the scope of this study which deals mainly with the administrative problems of arson investigation, the law enforcement efforts involved in arson cases are by no means free from the orbit of political influence.

It has long been recognized that overinsurance is a factor encouraging incendiarism. With a large number of fire insurance company agents working independently and in competition with each other in any given area, it appears that insurance can be secured on virtually any property, no matter how bad a risk it is.[19] The fire insurance companies have made sincere and most admirable efforts to prevent arson and to "bring home to every citizen that arson is a crime against the state and not a contest between an insurance company and a policyholder, and to make citizens conscious of the fact that the law-abiding purchasers of insurance are the ones who pay for the losses caused by the lawlessness of arsonists."[20] The National Board of Fire Underwriters, the Mutual Investigation Bureau, and the Fire Underwriters Investigation and Loss Information Bureau of Canada (which cooperates with U.S. agencies), maintain clearing houses for information on arsonists and property owners having questionable fire experience records. If more effective use were made of these or similar facilities, not only would the insurance companies benefit but in localities where the incidence of incendiarism is substantial a marked reduction in property losses could be achieved. In certain cities and states insurance agents can check new insureds against the records of the local fire departments or state fire marshals, but a nationwide system would be preferable and more effective.

[19] *Municipal Fire Administration* gives a classic example in this report: "A New York City Fire Marshal, as a stunt, furnished a room with three or four dollars worth of second hand furniture and succeeded in getting insurance totaling several hundred thousand dollars written on it." See p. 546.

[20] Letter of A. Bruce Bielaski to the writer, November 14, 1950.

Transporting Hazardous Commodities*

By Roy C. Petersen
Chief, Office of Safety, Port of New York Authority

Each of the transportation fields has its own fire problems, related to the type of equipment involved. Railroads have their individual problems with their rolling stock, truckers with their motor vehicles, steamship companies with their ships, and airlines with their aircraft. Each is a separate field, requiring separate treatment.

There are, however, two fire problems common to these three fields of transportation. The first lies in the commodities handled, and the second is in the terminal facilities. Let us consider in this article the first item, commodities handled. There are many. Which are hazardous? Which are flammable? Which ones present stowage problems? In the United States, Interstate Commerce Commission (I.C.C.) red, green, yellow or white labels on material have been a partial guide to fire protection engineers for years. These labels, and the regulations requiring their use had a very humble beginning; at first they only covered explosives, but the regulations have since grown to cover all dangerous articles and to include the construction and design of containers and boxes, as well as bulk units, such as tank cars, tank trucks and large portable containers.

These I.C.C. regulations, however, apply primarily when dangerous cargo is transported in inter-state commerce and, therefore, do not apply when the movement of the dangerous articles is confined within a state, unless under specific carrier conditions. For example: A manufacturer could make and pack material of a dangerous nature in one part of a state and carry it to another part of the same state without any form of identification label, so long as there were no state or local regulations restricting such movement or packing. Some states have specific rules and regulations governing the transportation of explosives, but make no mention of other dangerous articles.

This situation, therefore, points to a serious potential fire problem. That is, proper identification of dangerous commodities under all conditions. We are all fairly familiar with the nature of explosives and everybody recognizes the hazards incident to their transportation. When it comes to other dangerous articles, however, there is little or no uniformity in existing state laws and a wide variation in local laws with regard to packaging, marking, labeling and transportation. The fire protection engineer cannot depend solely on his nose nor can he have a chemical laboratory at his elbow to conduct special tests. To remedy this situation, there is need for uniform marking and labeling of products, so all concerned will know what is being handled.

The need for proper identification of commodities has been recognized by many of the large manufacturers and large industries, and they, by the use of the I.C.C.

*Based on a talk presented before the Transportation Group Session at the 55th Annual Meeting of the NFPA, Detroit, Mich., May 10, 1951. (Program Item No. 84.)

labels, whether required or not, as well as special "Caution" or "Warning" labels of their own design, convey information on the nature of the contents of a package or a drum. The Manufacturing Chemists' Association has advocated the use of MCA warning labels on certain types of chemicals.* The Compressed Gas Association and similar trade associations have also advocated proper labeling and marking of products and commodities, but unfortunately, all industries do not fully abide by this good thinking.

The identification of dangerous cargo would obviously be greatly simplified, if all states had identical regulations pertaining to packaging, marking and labeling. Individual state laws, however, probably would lead to considerable confusion due to varied opinions on what constitutes a hazardous commodity and how they should be handled. It would seem much easier, therefore, if states either adopted or duplicated the I.C.C. regulations pertaining to transportation of dangerous articles, rather than have each attempt to formulate regulations of their own.

*See Manual L-1 published by the Manufacturing Chemists' Association, Inc., 246 Woodward Bldg., Washington 5, D. C.

I.C.C. Regulations

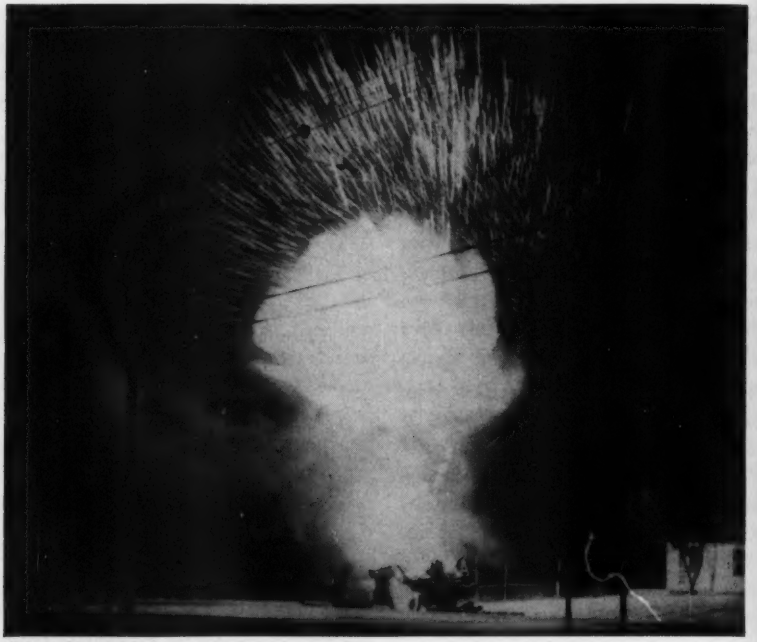
The I.C.C. by their regulations, set up a series of classifications, to cover all types of dangerous articles. These are:

Explosives, Classes A, B and C.
Flammable liquids—80°F. or less.
Flammable solids and Oxidizing material.
Corrosive Liquids (Acids and Alkalies).
Compressed Gases—Flammable.
—Non-Flammable.
Poisons—Classes A, B, C and
—Radioactive material, Poison, Class D.

Somewhere along the line, between the manufacturer and the consumer, these dangerous articles must move in either inter-state or intra-state commerce, passing through railroad or motor truck terminals, through piers and even through airports.

Courtesy Citizen Fire Co. Inc. (Charles Town, W. Va.)

This dwelling, and one other, were destroyed by an explosion in a tractor-trailer truck hauling 15 tons of dynamite. The truck was proceeding along U. S. Route 340 in a rural area near Halltown, Pa. at 4:40 A.M., Feb. 1, 1951, when fire was discovered at the tractor gasoline tank. It is believed that a broken tire chain punctured the tank and escaping gasoline ignited. The driver warned the occupants of the dwelling in time and no one was killed.



Wide World Photo

Tires have been a serious source of fire in recent years. This truck, loaded with 44 oxygen and 27 acetylene cylinders, stopped to change a flat on U. S. Route 81 in open country near Austin, Texas on Jan. 27, 1951. While the vehicle was thus standing still, the tire blazed, ignited the wooden bed of the truck and the heat caused the acetylene tanks to explode. The fire department was able to control the blaze and prevent a grass fire. Windows in nearby buildings were shattered.

Trucking Hazardous Commodities

The increasing movement of dangerous cargo by motor carrier in the last few years has further expanded this dangerous cargo fire problem, not only to the trucking industry but also to the public fire departments who are charged with the protection of the public. Dangerous cargo, shipped by rail is confined to rails, on a private right-of-way, or to a private freight yard, whereas dangerous cargoes shipped by motor carrier, travel over the open highway, through crowded city streets, over bridges, through tunnels and even over ferries. The fire potential exists and must be fully recognized, not only by the trucker, but also by the terminal operator, the bridge, tunnel and ferry operator, and as well, the local fire department for their own benefit and for public safety.

A placard on all trucks to identify the contents is vitally important. An *interstate* or *common carrier* is required to placard a truck transporting quantities of dangerous articles. However, what about the *private carrier?* He probably would *not* be required to placard a truck, unless a state law or some local requirements so stated.

It may be of interest to learn that, in 1950, the New Jersey State Legislature

recognized the need for such placarding and enacted a State Placarding Law.* The New York Legislature also recognized the need and, in 1951, passed a similar law which has been approved by the Governor and is now effective.

Port Authority Truck Problems

I would like to cite some of the Port of New York Authority's experience in connection with the transportation of dangerous articles and placarding of trucks. The Port Authority, in its operation of the Holland and Lincoln Tunnels, and other crossings between the states of New York and New Jersey, accommodates an average of 20,000 trucks per day, over 1,000,000 vehicles (both trucks and passenger cars) per week.

While it is not possible to make a complete inspection of each and every truck that is to travel through these tunnels, it is our practice to carry on an extensive system of spot inspections and checks to forestall the possible transportation of extremely dangerous cargo through the tunnels. The Port of New York Authority from the time the Holland Tunnel opened, had set up specific rules pertaining to the transportation of dangerous articles through its tunnels. These rules recognize the regular I.C.C. definitions and require that all commodities shipped through the tunnel conform to such regulations with regard to packaging, marking, and labeling. Because of the confined nature of the tunnels and the importance of providing the maximum of protection and safety to the traveling public, definite limitations on certain types of dangerous cargo and absolute prohibitions of other types of dangerous cargo had to be established.

*Chapter 128, Laws of 1950, State of New Jersey.

During 1950, a total of nearly 115,000 trucks were inspected in our program of truck inspections, to detect hazardous cargo. Many trucks (556) were turned away, inasmuch as their cargo was of a hazardous nature and in quantities in excess of that permitted by our specific safety regulations. These vehicles were not stranded; they had the choice of using the George Washington Bridge, or the special "Dangerous Cargo" ferry that runs between New Jersey and New York solely for the purpose of carrying extremely dangerous materials.

Holland Tunnel Fire

On May 13th, 1949, a Port Authority emergency crew was faced with a serious fire situation in the south tube of the Holland Tunnel. A closed van truck, loaded with some 44,000 pounds of carbon disulphide became involved in a fire which developed into a major fire fighting problem and resulted in closing the south tube for three days, and a half-million dollars damage. This truck escaped detection on our plaza because of the lack of adequate placarding or marking. Eye witnesses stated they saw the back of the truck blow open and the truck swerve from one lane into the other, completely blocking the tunnel. Over 100 trucks and passenger cars were behind that vehicle, jamming the tunnel to its New Jersey portal.

The story of this first sensational chemical fire within a sub-aqueous vehicular tunnel is past history. It made the front pages of the newspapers all over the country and was the subject of a very complete report by the National Board of Fire Underwriters. A report was also published in the NFPA *Quarterly*.*

*See July 1949 *Quarterly*, page 78.

Acme

One of the ten vehicles damaged by the explosion and fire in the Holland Tunnel on May 13, 1949, when a 16-ton trailer truck loaded with eighty 55-gallon drums of carbon disulphide caught fire.

I will not repeat the story, but would like to cite some of the things that this fire did, that were not published. The fire demonstrated the fire resistance of the tunnel structure. It justified the communications and electrical control designs of over twenty years' standing. It demonstrated the efficiency of the tunnel's vertical ventilating equipment. Horizontal ventilation would have tended to spread smoke and the gases throughout the tunnel, whereas the vertical ventilation greatly reduced and measurably controlled the spread of smoke. Another important lesson learned from the fire is that the I.C.C. rules and regulations governing the transportation of explosives and dangerous articles are not self-enforcing and were not fully understood or practiced.

Present PNYA Truck Inspection Program

Regulations of the Port Authority restricted the transportation of explosives and dangerous articles in the interest of public safety, and spot-checks were continuously under way. Since the fire, a more intensive program of inspection of trucks has been conducted; the following statistics give an indication of the current program:

1950 Vehicle Inspection

Holland Tunnel	Lincoln Tunnel
Total—4,071,863	Total—2,919,207
Inspected—62,039	Inspected—50,385
Turned away—433	Turned away—108

I would like to just cite a few cases from our inspection records, to give an idea of what types of commodities are actually moving over the highways and what fire potentials actually exist. Bear in mind that the trucks cited here are all in inter-state commerce and that I.C.C. regulations require placards on such trucks when carrying an excess of 2500 pounds of flammable liquids, flammable solids, oxidizing material, compressed gases or corrosive liquids.

1. A truck loaded with 15 drums xylol, weighing 8100 pounds, each drum bearing a "red" flammable label, but the truck carrying no warning placards.

2. A truck loaded with 111 drums of lacquer thinner, each drum bearing a red label. The truck bore no I.C.C. placards. There were approximately 26,035 pounds of material involved in this shipment, all of a very low flash point.

3. A semi-trailer, loaded with 23,518 pounds (62 drums) of red label chemical, identified on the shipping papers as Triethylamine (20°F. flash point). The shipping papers were not complete. The truck did not carry any placards.

4. A truck containing 33,913 pounds of Toluol, in 55-gallon drums, each carrying the red label, but with no I.C.C. warning placard on the outside of the truck.

These are just a few of the specific cases. Other trucks have been refused by reason of their carrying large quantities of hydrochloric acid and formic acid; some trucks for carrying anhydrous ammonia or hydrogen gas in cylinders. One of the most recent pick-ups was a truck bound between New York and New Jersey, carrying a large number of cylinders of liquid chlorine, not only in violation of the I.C.C. regulations, but also in direct violation of the New York City regulations. Upon its discovery, the New York City Police and New York City Fire Department immediately took charge. Chlorine, incidentally, is one of the compressed gases absolutely prohibited from transportation through the Port Authority tunnels.

Courtesy The Port of New York Authority

Port Authority police checking a tractor trailer at one of the tunnel entrances. This New Jersey registered vehicle was found to be carrying a red label "Aroplaz" (protective coating material).

Hazardous Cargo Storage

I am sure there is no question about the desirability of knowing what is moving as far as the bridge, tunnel, ferry operators, or local fire departments are concerned. What about others? Just consider where else dangerous cargo is apt to turn up. First, we have the hazard in the manufacturing plant itself. There it is undoubtedly recognized and fully known. Secondly, we have the potential hazard existing either in a warehouse or a freight station, in a railroad car or a motor truck at its point of destination, or on a pier and later in the hold of a steamship. All along the line, dangerous cargo presents a handling and storage problem.

Any material, when properly labeled is identified and gives the warehouseman, handlers at the freight station or the terminal, or the terminal operator, the opportunity to exercise proper precautions by careful handling, proper storage or segregation. I do not speak solely of flammable liquids or solids, but also of the corrosive liquids, compressed gases, poisonous gases and substances. In many cases, the articles by themselves are not over-hazardous, from the fire standpoint. However, when involved in a fire, they either intensify the blaze or make fire fighting next to impossible.

U. S. Coast Guard Regulations

How about this problem of dangerous cargo from the marine or marine terminal angle? The I.C.C. regulations, while applicable when the material is in inter-state transit either by rail or over the road, generally cease to apply when the material actually reaches its destination or it is deposited at a waterfront facility, such as a pier or dock. This situation is especially true when the material is bound out of the country or is to be transported by water from one part of the country to another. At this point of the journey, the U. S. Coast Guard regulations entitled, "Explosives and Other Dangerous Cargo on Board Vessels," which are closely patterned after the I.C.C. regulations, become effective. (There is actually a regulatory "no-man's-land" on the pier if the regulations are strictly interpreted.)

These Coast Guard regulations apply to the movement of dangerous cargo by ship, although they apply equally where dangerous cargo is on a motor truck using a ferry to cross a navigable waterway within the United States. (In this latter case two sets of regulations actually apply, the I.C.C. regulations by reason of the inter-state commerce and the U. S. Coast Guard regulations by reason of the trans-shipment on water.) The U. S. Coast Guard regulations include all of the I.C.C. dangerous cargo classifications and also provide two additional classifications. One applying to "Combustible Liquids" (liquids which give off flammable vapors at temperatures below 150°F. and above 80°F., Tag. open-cup) and the other to a class of material called "Hazardous Articles." Although labels are required to identify all dangerous cargo in the I.C.C. classes, no special label is required for these two additional classifications.

This method of marking and identification serves fairly well within the confines of this country, but what about cargo that is inbound? What regulations cover such cargo? Generally, dangerous cargo shipped into the U. S. will have U. S. labels applied inasmuch as the importer is required by U. S. C. G. regulations to furnish the shipper with the necessary identification markings. However, you will also find that most of the foreign countries have regulations which are very similar to

our U. S. Coast Guard regulations and our I.C.C. regulations. Similar methods of labeling and marking are used.

Education of the stevedores, the warehousemen and terminal operators in the identification of dangerous articles as well as safe handling is only part of the problem. The other is the limitation or complete prohibition of some cargoes, or the specific control over storage and handling operations of the hazardous cargo. Together they help to control the fire problem. Some ports or terminals have set up a Port Warden or special officer who is charged with port protection and who, by his authority, grants permits for the movement of hazardous and dangerous cargoes through the area.* By this method, the terminal operator or the Port Warden can readily determine the extent of movement of dangerous cargo through the area under his jurisdiction. The U. S. Coast Guard also takes a hand and controls the movement of explosives or other highly dangerous commodities by a permit system.

Any system of regulation, whether by the U.S.C.G., I.C.C., local authorities or individual corporations or agencies, is not designed to prohibit the movement of necessary commerce, but to prescribe safe packaging, proper marking, proper storage and handling methods and to know exactly what is moving and how much is moving. The extent of fire protection actually is planned on the basis of the hazard, therefore, knowing the hazard one can plan for adequate protection to take care of the emergency.

*See NFPA pamphlet "Security of Port Facilities and Ships in Harbors," available from the NFPA Executive Office, 25c per copy.

Port Authority Practices

The Port of New York Authority, in its operation of 27 ship berths in the Port

Courtesy The Port of New York Authority

When goods arrive at marine terminals, as at this Port Authority Columbia Street Pier, fire safety becomes a major problem.

Courtesy The Port of New York Authority

Interior view of Port of New York Authority Union Motor Truck Terminal. This terminal, dedicated Oct. 31, 1949, cost $10,000,000 and occupies four city blocks. Note that the terminal is protected with automatic sprinklers and that pallets are extensively used in handling goods with mechanical equipment.

Newark area, together with more than 600 acres of storage land with warehouse and tenant buildings, as well as its operation of six ship berths at the Columbia Street Pier and Grain Terminal facility, keeps rather close watch on the nature of the commodities passing over the piers and wharves. Port Authority regulations prohibit the transfer of Class A explosives and control other dangerous cargo. By this method, both industry and commerce are being served with the least degree of exposure or risk.

For example, chemical cargo is divided into the hazardous and non-hazardous classes. Extremely hazardous material is stored in separate buildings, so as not to expose the non-hazardous material. As a result, the insurance cost on millions of dollars of value is not increased due to ten thousand dollars' worth of hazardous goods.

Similarly, if a shipload of sisal or similar fiber is handled, it is channelled through a sprinklered property and additional fire precautions taken during the operation. Such precautions as protecting aisle material with tarpaulins, checking the fire safety of tractors and setting of fire lines for immediate action are standard operating procedures. In addition, cargo is interspersed, aisles are maintained and all cargo is removed as rapidly as possible. These requirements are not sprung upon a stevedore or steamship company or warehouse operator. They are all spelled out beforehand as part of the lease and operating

regulations. Constant alertness on the part of the facility superintendent and our security force make them workable. Most of these good practices are contained in the NFPA Standard No. 307 "Operation of Marine Terminals" adopted in 1951.*

The benefits of automatic sprinkler protection in warehouses, transit sheds and piers, especially when handling dangerous cargo, cannot be over-emphasized. In assuming the operation of the Port Newark area, under lease from the City of Newark a little over two years ago, an immediate rehabilitation program was started to fully restore sprinkler protection to the warehouses and transit sheds. In addition, in the construction of two new transit shed facilities at Port Newark, we provided a modern sprinkler system designed to protect both the buildings and the vital commerce that passes through them. At present, the installation of automatic sprinkler protection at the old Columbia Street Pier of the New York State Barge Canal Terminal in Brooklyn is under way as part of a pier improvement program. Here, a complete system of automatic sprinklers is being installed in the pier shed, arranged on a combination automatic dry pipe and pre-action type system (either functions separate of the other). Instead of the usual six or eight individual dry systems, all are tied together and supplied by two dry pipe valves set in parallel, operating either automatically by differential action or by the rate-of-rise thermoelectric pre-action equipment. This is a new method of applying old principles to effect better fire control.

*Copies of NFPA No. 307 are available from the NFPA Executive Office at 25c per copy.

Courtesy The Port of New York Authority

A group of Army Transportation Officers inspect the air cargo facilities at Newark Airport. Civil Air Regulations (Part 49) cover the transportation of explosives and other dangerous articles by air in a similar manner that U. S. Coast Guard regulations govern marine shipments and stowage.

Air Cargo

During the last decade, air transportation has grown by leaps and bounds, and the Berlin airlift demonstrated what could be done in the field of cargo transport. At the three airports in the New York metropolitan area — Newark, LaGuardia and New York International — operated by the Port of New York Authority, in one month, January, 1951, 2,885,000 pounds of airmail and 16,980,000 pounds of air freight were handled by a total of 22,417 aircraft movements. These figures, although staggering, only cover three airports out of hundreds in the country.

Air cargo operation varies from the transportation of wild animals to radioactive isotopes, the latter with such a very short life that without air transportation they would be worthless. Here again is another field of transportation where certain regulations pertaining to dangerous cargo must be applied for public safety.

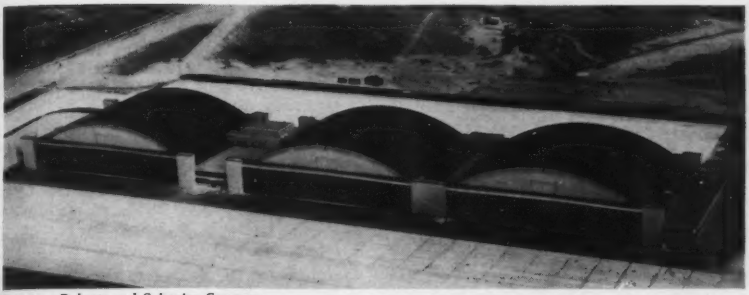
Just as I.C.C. regulations cover transportation of explosives and other dangerous articles by rail and motor carrier, and the U.S.C.G. regulations cover transportation by water, the Civil Aeronautics Board by Part 49 of the Civil Aeronautics Regulations covers the transportation of explosives and other dangerous articles by air. These regulations follow the pattern of the U.S.C.G. regulations and similarly require dangerous cargoes to be marked, labeled and packaged according to the I.C.C. requirements.

For safety reasons, it is natural that these regulations be highly restrictive and prohibit air transportation of some articles completely and limit air transportation of other dangerous articles to cargo planes only. Airlines in general set up their own regulations and a personal inquiry of several revealed that the airlines, on their own initiative, prohibit the shipment of many dangerous cargo items on their passenger flights and are extremely cautious on the types of dangerous cargo they will accept for air transportation. Compatibility in storage is a most important factor in all fields of transportation but is even more important in the air transportation field due to the limited space and stowage conditions. Let me relate an incident told me by one of the airline officials that emphasizes this point.

An air shipment of unexposed X-Ray film was placed in the freight compartment, with other freight. It arrived safely at its destination and was delivered. The film was found to be defective. The trouble was finally diagnosed as partial exposure. The investigation made by the airline revealed that the film had been shipped with a package of radioactive material and thereby destroyed within its own package. Here again, the only solution is education of those persons charged with loading of ships or with the handling of cargo.

Protecting Air Cargo on the Ground

The quantity of dangerous cargo moving by air is not too large, and, therefore, does not quite present the serious problem encountered in marine or land transportation. However, all air cargo is generally a little more valuable or more perishable than that transported on land. It deserves protection against theft and fire hazards. Air cargo should be handled from regular cargo buildings, rather than from a corner of an aircraft hangar or a shop, as is quite common at the present time. Efforts to establish separate cargo buildings were made at New York International Airport with considerable success, and just recent-



Courtesy Roberts and Schaefer Company

The new hangars constructed at New York International Airport. Each hangar (65,400 sq. ft. floor area) has six deluge type sprinkler systems supplied at present, by large capacity city mains. A secondary water supply source is under construction, including a pumping station and a million-gallon reservoir.

ly, a very large cargo-operations building was completed at that airport. Protection of the valuable air cargo was fully recognized, so fire-resistant construction was designed and further fire control effected by the use of a complete wet pipe sprinkler system.

Aircraft Fire Safety Challenging

Undoubtedly no other field of transportation presents the fire protection and prevention problems that arise in the field of air transportation. The hazards of storing and handling millions of gallons of gasoline is only one part. The servicing hazard on costly aircraft, with various cleaning operations, defueling, repainting, recharging of oxygen systems and other associated services make up the balance of the problem.

Modern transport aircraft, costing generally over one and one-half million dollars each, require extensive hangars for service operations, with the result that fire protection itself for these high valued structures and their contents runs into considerable money. Adequate fire protection of hangars is a must if you desire to protect your investment and stay in business. The Port Authority in developing New York International Airport, recently constructed three large hangars, valued at about $9,000,000. These hangars are among the largest in the world, being 300 ft. by 218 ft. (65,400 square feet) each and are 85 ft. high at the top of the center arch. Each hangar is protected by six automatic deluge systems presently supplied by 30-inch and 36-inch water supply connections from 48-inch and 72-inch city water mains. To insure better water supply and to provide for a secondary source, as well as provide improved fire protection for the other buildings over the 4900-acre airport tract with its 13 miles of 36-inch riveted steel and 11 miles of cast iron high pressure fire mains, a new fire pumping station is nearing completion. This station, the largest of its kind, with its large city supply mains and 1,000,000-gallon storage reservoir, will deliver approximately 35,000 gallons per minute at 165 pounds of pressure into the miles of high pressure fire mains that cover the airport. The fire problem with regard to gasoline storage and handling operations has been controlled by the adoption of a set of safety regulations for aircraft refuelers (tank trucks), involving periodic inspections, the control of fueling and defueling, and the segregation of the storage facilities.

For instance, the latest expansion of the fuel storage facility at New York International, which is approximately two and one-half miles from the Terminal area includes construction of tanks that will store a total of approximately 3,000,000 gallons of aviation gasoline. This large storage facility is absolutely necessary inasmuch as there are almost 800,000 gallons of aviation gasoline dispensed each week for overseas flight operations. This facility expansion is being designed with the latest gasoline handling equipment and a complete mechanical foam fire protection system is presently being built in.

I have taken the liberty of referring to some Port Authority operations during this talk solely to emphasize my point of facing problems in the beginning. By planning and utilizing known principles of fire protection, the fire problem can be controlled.

Bibliography of Pertinent Texts

(*See also footnotes*)

Publications of the National Fire Protection Association

The National Fire Protection Association has more than 300 different publications covering various phases of fire protection and fire prevention. A complete list is available upon request. Supplementing the information in this article the following is a selection of related material.

Aviation

Airplane Crash Fire Fighting Manual. 1945. 96 pp. $1.00.

Standard Operating Procedures, Aircraft Rescue and Fire Fighting. NFPA No. 402. 1951. 28 pp. 35¢.

Suggested Aircraft Rescue and Fire Fighting Equipment for Airports. NFPA No. 403. 1951. 36 pp. 50¢.

NOTE: *For other NFPA aviation material request listing of publications issued by the NFPA Aviation Committee.*

Marine

Developments in Waterfront Fire Protection. By R. C. Stange, Chairman, NFPA Committee on Piers & Wharves. July 1948, NFPA *Quarterly,* pp. 8-21. $1.50

Boatyards and Marinas, Recommendations for Fire Protection of. NFPA No. 303. 1951. 28 pp. 25¢.

Gas Hazards on Vessels to be Repaired, Control of. NFPA No. 306. 1951. 16 pp. 15¢.

Motor Craft, Fire Protection Standards for. NFPA No. 302, 1951. 36 pp. 35¢.

Marine Terminals, Recommendations for Operation of. NFPA No. 307. 1951. 24 pp. 25¢.

Petroleum Wharves, Suggested Ordinance for. 1938. Adopted by National Board of Fire Underwriters and NFPA. 10 pp. 10¢.

Piers and Wharves, Suggested Ordinance Regulating the Construction and Protection of. 1941. Adopted by American Assn. of Port Authorities, National Board of Fire Underwriters, and NFPA. 24 pp. 25¢.

Vessels During Construction, Repair, and Lay-Up, Recommendations for Fire Protection of. NFPA No. 312. 1951. 16 pp. 15¢.

Truck Transportation

Report of Committee, 1938, 20 pp. 10 cents.

Publication of the National Board of Fire Underwriters

Construction and Protection of Airplane Hangars, NBFU Pamphlet No. 85, Oct. 1950. 42 pp. Free.

Publication by H. A. Campbell, 30 Vesey St., New York 7, N. Y.

"Transportation of Explosives and other Dangerous Articles by Land and Water in Rail Freight Service and by Motor Vehicle (Highway) and Water" (Tariff No. 8 publishing Interstate Commerce Regulations) $3.50 (included subscription to Supplements for 3 years).

Publication by Supt. of Documents, U. S. Gov't Printing Office

"Explosives or Other Dangerous Articles on Board Vessels" (Regulations Prescribed by the Commandant of the Coast Guard). $1.50.

"Transportation of Explosives and Other Dangerous Articles," Part 49, Civil Air Regulations. 10¢.

New Test Apparatus For Dust Explosions

By Paul E. Cotton, Research Engineer
Factory Mutual Laboratories

The dust explosion hazard is not new to industry* nor are the methods for protection against dust explosion damage. However, except for a certain few materials for which field experience, costly both in terms of loss of life and property damage, has been gained, the fire protection engineer has had to rely largely on judgment in determining the protection necessary for any particular hazard. Laboratory methods for evaluating the hazard of dusts have been inadequate for the task of providing a firm basis for translation from test results to field recommendations. Yet the only practical solution to the problem lies in a laboratory evaluation of the hazard inherent in a given dust.

Laboratory methods should be capable of evaluating all of the factors which, together, govern the hazard of a dust. Methods previously used have given information in terms of the explosion pressure developed by a sample of the dust when it is dispersed in air inside a closed chamber containing an ignition source. Although these data do give some measure of relative hazards of different dusts, they afford a meager basis for estimating the hazard of a particular dust under practical conditions. The methods also had the particular disadvantage of giving negative results with some materials which could be dangerous under some conditions.

The characteristics of a dust which the fire protection engineer needs to consider are:

1. The energy available through combustion of the dust and the rate at which it is released in the dust explosion process, since these factors determine the pressure venting requirements.

2. The dispersibility of the dust, or the energy required to produce a dust cloud that will burn, since this information assists in judging the probability of a combustible dust cloud being produced under actual field conditions. The dispersibility is affected in most combustible dusts by moisture content and particle size.

3. The ignition temperature which determines whether or not ignition sources likely to be present are capable of igniting the dust.

4. The range of concentration in which fine dust particles mixed with air may be explosive, since this information is an assistance in judging whether dust accumulations might be sufficient to be dangerous.

The Factory Mutual Laboratories have developed a testing device designed specifically to evaluate these dust properties and thereby to improve the basis for recommendations for protection.

Although the test conditions are designed to give positive results, no attempt was made to produce dust explosions of maximum efficiency. With a different de-

*Dust explosions have been responsible for many disasters involving loss of life and extensive property damage. A partial list of serious dust explosions occurring in the United States appears in Appendix C of National Fire Codes, Volume II (published 1950 by the NFPA). In the 936 explosions listed in this reference, 598 persons were killed, 1,466 injured and more than $90,000,000 property damage suffered.

sign it may be possible to produce slightly higher closed chamber pressures than with this device; however, the objective of this apparatus is to produce a maximum of useful information with a reasonable amount of manipulation and expenditure of test time by the laboratory technician. However, we believe that conditions are at least as favorable as any that might exist in practice in a room or piece of equipment.

Apparatus

Figure 1 illustrates the new testing device mounted on a panel together with its associated controls. It consists of a chamber in which a cloud of the dust to be tested is dispersed and ignited. However, it is so arranged that the effects of venting, dispersal energy, ignition temperature and dust concentration can be determined. The various functions of the device are better illustrated by the diagramatic sketch, Figure 2. The explosion chamber itself is an 18-inch length of standard 4-inch aluminum pipe with an internal volume of 0.13 cu. ft. It is equipped with notched flanges on both ends so that top and bottom caps, also made of aluminum, can be attached, pressure tight, by a one-eighth turn.

The receptacle in which the dust sample is placed for dispersion into the explosion chamber is the 5-inch long, ½ inch brass nipple connected to the bottom cap of the chamber.

As shown in Figure 2, the electrically heated nichrome wire coil which serves as the ignition source is supplied from a variable transformer by means of which the coil's temperature is controlled. Any desired temperature, up to nearly 2000°F can be obtained with this arrangement by use of a calibration curve for the coil showing the relationship between coil current and coil temperature as measured by a thermocouple welded to the coil.

The top cap of the chamber is equipped with a vent hole in which six-inch-long

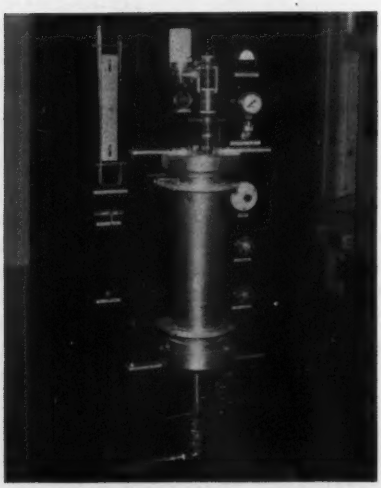


Figure 1. The dust explosion test chamber and associated controls developed by the Factory Mutual Laboratories. Note that the dust sample receptacle is located between the bottom cap of the aluminum chamber and the union which connects it to the air supply hose.

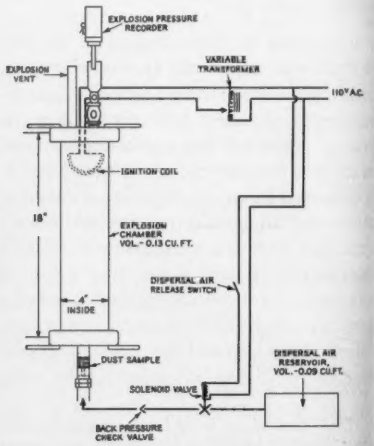


Figure 2. This sketch (not to scale) shows the dust explosion test chamber illustrated at the left. Here it can be seen where the 3-inch nipple (below the chamber) holds the dust sample. The ignition coil shown permits temperatures up to nearly 2000°F.

vent tubes of various diameters can be placed. The purpose of these short tubes is to direct products of combustion into the laboratory exhaust system without serious restriction of the vent area. Provision is made for ¼ inch, ½ inch and ¾ inch vent sizes giving vent ratios of 0.54, 1.60 and 2.81 sq. ft. per 100 cu. ft. of volume respectively.

Procedure

In the normal procedure for preliminary tests a thin wafer of absorbent cotton, just large enough to cover the orifice, is placed over the insert in the sample receptacle, then a 3-gram sample of the dust to be tested is placed in the receptacle by pouring directly into it through the bottom cap. After attaching the cap to the chamber and connecting the ½ inch union, air is supplied to the dispersal air reservoir to a pressure of 20 psi and the igniter coil is heated to 1600°F by proper setting of the variable transformer.

With these conditions established, the dust explosion is initiated by closing momentarily the dispersal air release switch which causes the solenoid valve to open and permits the dispersal air to blow the dust sample into a cloud in the closed explosion chamber where it is ignited by the hot coil. The resultant pressure is recorded on a steam engine type of pressure recorder, which is sufficiently fast in its response to record with substantial accuracy the pressure increases encountered in dust explosion tests.

Since a pressure of about 8 psi will be shown on testing an inert material under closed chamber conditions, it may be assumed for most practical conditions that a sample has no dust explosion hazard unless the record substantially exceeds 8 psi.

The test conditions used in the preliminary procedure described above are basic conditions designed to avoid the negative results sometimes produced by previously used apparatus with dusts known to be combustible. A 3-gram sample gives a concentration of 0.8 oz. per cu. ft. which is well within the explosive range; the ignition temperature (1600°F) is high enough to ignite all organic and most metallic materials that are combustible; and the 20 psi dispersal air pressure was found by test to be sufficient to disperse almost all materials which tend to clump together.

Factors Influencing the Hazard

The evaluation of the effect of any single factor in the dust explosion hazard is made by varying that factor while maintaining the other basic conditions constant. For example, to determine the relative available energy and the effect of venting (which is an indirect measure of rate of pressure rise), tests are conducted with the chamber closed and with the various size explosion vents while maintaining sample size at 3 grams, temperature at 1600°F and dispersal pressure at 20 psi. A plot of the resultant pressures versus vent ratio would show to what extent the explosion pressure is reduced by various size vents.

To demonstrate the evaluation of venting effect, data are given in Table I for samples of four materials, aluminum flake, cornstarch* (moisture content 11.5%), confectioners' sugar (moisture content 0.2%) and cocoa (moisture content 7.2% and fat content 17%). The closed chamber pressures show roughly the relative explosion energy available from these materials; and the pressure reduction due to venting gives added information on the rate of release of that energy. Aluminum, having a high rate of pressure rise produces 56% of its closed chamber pressure when a ¾ in. vent is used, whereas the cocoa explosion pressure is reduced to about 1% of its closed chamber value when the ¾ in. vent is used.

*This was a sample of ordinary commercial cornstarch and not a sample of special candy molding starch.

TABLE I

Effect of Vent Size on Explosion Pressure

Vent Sizes Inches	Vent Ratio		Explosion Pressure-PSI (Average 5 Tests) Produced by Following Materials			
	Sq. Ft. per 100 Cu. Ft. of Volume	Cu. Ft. of Volume per Sq. Ft.	Aluminum	Cornstarch	Conf. Sugar	Cocoa
Closed	...	...	137	101	76	86
¼	0.54	185.	116	62	55	47
½	1.60	62.5	86	41	34	11
¾	2.81	35.6	77	25	20	<1

TABLE II

Effect of Dispersal Air Pressure on Explosion Pressure (Chamber-closed)

Dispersal Air Pressure - PSI	Explosion Pressure - PSI (Average 5 Tests)			
	Aluminum	Cornstarch	Conf. Sugar	Cocoa
30	138	105	85	100
20	137	101	76	86
10	107	86	66	71
5	82	73	56	59
3	66	56	46	46
2	66	50	36	35
1	43	10	7	33

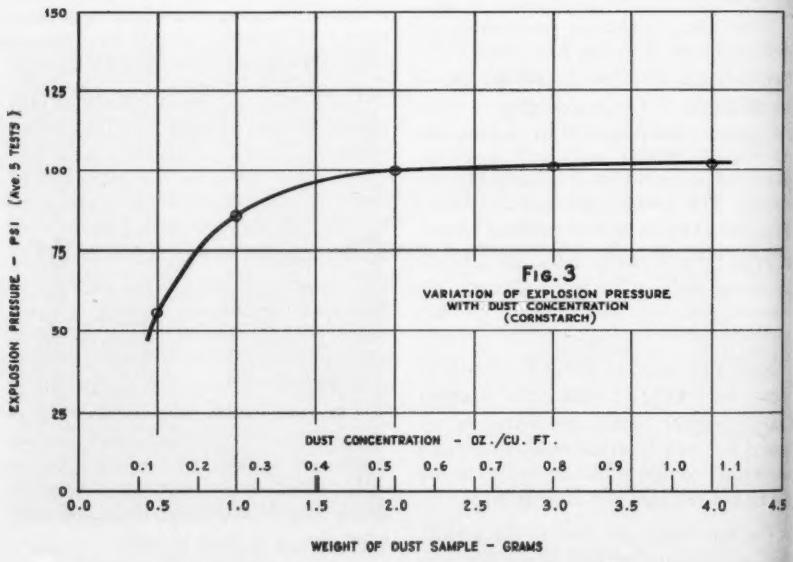

EXPLOSION PRESSURE - PSI (Ave. 5 TESTS)
150
125
100
75
50
25
0
FIG. 3
VARIATION OF EXPLOSION PRESSURE WITH DUST CONCENTRATION (CORNSTARCH)
DUST CONCENTRATION - OZ./CU. FT.
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
WEIGHT OF DUST SAMPLE - GRAMS

Figure 3. Three grams of cornstarch are normally used in evaluating dust explosion hazards with this material. This gives a 0.8 oz. per cu. ft. concentration and it can be seen from this graph that this sample is representative of maximum dust concentration conditions as there is no significant increase above this value.

Similarly, the relative dispersibility of these materials is indicated in Table II, which shows the reduction in explosion pressure due to reducing the dispersal air pressure. The difference in the dispersibility among these four materials is not fully apparent until the dispersal air pressure is reduced to less than 2 psi. At these low pressures the difficulty of dispersing cornstarch and confectioners' sugar as compared with aluminum and cocoa becomes apparent.

A typical example of the evaluation of dust concentration effect is given by the graph for cornstarch in Figure 3. This shows how explosion pressure varies with dust concentration. It is evident from the graph that the "normal" test concentration (3 grams=0.8 oz/cu. ft.), being in the flat portion of the curve, is representative of maximum dust concentration conditions since for cornstarch there is no significant increase in explosion pressure due to increasing concentration above this value.

The ignition temperature data for the four dust-air suspensions are given in Table III. It should be noted that these values are qualified by the design of the igniter coil. That is, a larger area of hot surface might give slightly lower values. However, the values give an indication of relative ignitibility of the materials.

TABLE III
Ignition Temperatures Below Which No Explosion Pressure Results

Aluminum	Cornstarch	Conf. Sugar	Cocoa
1250°F	800°F	1000°F to 1100°F	1200°F to 1300°F

In establishing a rating of hazard or when applying the test information to a specific protection problem, it is necessary to assign more significance to some factors than to others. For example, the explosion pressure in a vented chamber, depending simultaneously on quantity of energy and its rate of release, is, in general, considerably more important than data on relative dispersibility and ignitibility. The vented chamber pressure is the controlling factor in determining the extent of the damage that will result from the usual accidental explosion. Ignition temperature, on the other hand, has relatively little importance because chance ignition sources will probably be sufficient to ignite any common hazardous materials such as cornstarch (800°F) and aluminum powder (1250°F).

Comparison of Laboratory Tests with Full Scale Tests

The relation of results from the laboratory test apparatus to full scale conditions can be demonstrated by comparison with tests made at the Factory Mutual Laboratories' Test Station at Norwood, Mass. A series of candy molding cornstarch* dust explosion tests designed to simulate typical industrial dust explosions were made in a specially constructed explosion chamber approximately 30 ft. long, 12 ft. wide and 12 ft. high (internal volume—4,170 cu. ft.). One end of this chamber was arranged to provide variable vent areas, either open or equipped with simulated hinged type factory sash.

The experimental dust explosions were produced by dispersing cornstarch* from a 1 ft. wide, 12 ft. long paper covered frame supported near the ceiling of the chamber along its long axis. Dispersion of the dust was effected by firing a single strand of primacord laid in the dust pile on the paper covered frame. At the same time, a small primary dust explosion was created by dispersing 1 lb. of cornstarch from a 3-in. diameter mortar located 4½ ft. below one end of the main charge on the frame. A black powder-magnesium mixture served to propel the primary dust charge from the mortar and ignite it. This burning primary dust cloud then passed into the main dispersion and ignited it in the same man-

*"Buffalo 126" cornstarch by Corn Products Refining Company.

ner as an incipient dust explosion might create and ignite a larger dust cloud under industrial conditions.

Figure 4. A typical dust cloud produced in the full scale tests at the FM's Norwood Lab. This view is from the open end of a 30 ft. long by 12-ft. wide by 12-ft. high chamber.

The form of the dust cloud produced by this dispersion method is illustrated by Figure 4.

The intensity of the test explosions was measured by the Factory Mutual Explosion Effect Gage,* which is a piston actuated instrument designed to register the same deflection as an average 12-in. brick wall, 16 ft. between rigid supports. The recorded distance which this gage is deflected by a test explosion is the same distance that the center of the brick wall would be deflected by the same explosion. Thus the gage provides a direct measure of explosion damage to a common type of industrial construction. While the gage may be designed to show deflection for other types of construction, the results of tests using a gage equivalent to a 12-in. brick wall are presented here as an example.

Full scale tests were made with 12 lb. cornstarch charges with vent ratios varying from 0.38 to 1.61 sq. ft. per 100 cu. ft. of volume using both open vents and factory sash type vents and with 24 lb. cornstarch charges using open vents of the same range of vent ratios. It is estimated from photographs that the 12 lb. and 24 lb. charges formed dust cloud volumes of 860 and 1,300 cu. ft. respectively, giving average calculated dust concentrations of .22 and .30 oz. per cu. ft. respectively. These dust charges are only about ¼ and ½ respectively of the amount that could be wholly consumed by the oxygen available in the total interior volume of the explosion chamber, because the purpose of the tests was to simulate probable industrial conditions. Since the optimum conditions for maximum explosion pressures are rarely if ever approached accidentally, it is believed that the quantities tested represent reasonably severe field conditions as nearly as those conditions can be estimated. Probably about 3 lbs. of dust per 1,000 cu. ft. is about all that may be expected to be dispersed simultaneously in ordinary manufacturing rooms. In small equipment like a mixer or dryer, much higher proportions may be expected.

To compare with the large chamber tests, standard tests were made in the new laboratory apparatus using the same grade of candy molding cornstarch (moisture content 9.9%; 100% through 200-mesh sieve). In addition to closed chamber conditions, the ¼ in., ½ in., and ¾ in. vent sizes were used giving open vent ratios ranging from 0.54 to 2.81 sq. ft. per 100 cu. ft. of volume.

For comparison, the results of the laboratory apparatus and of the full scale tests are presented on Figure 5. These graphs show the relationship between explosion intensity and vent ratio of both test methods, the explosion effect coordinate being graduated in psi pressure for the laboratory apparatus results and in hundredths of an inch deflection on the Factory Mutual Explosion Effect Gage for the large chamber test results.

The comparison provides a basis for predicting from laboratory apparatus results what damage could occur under actual industrial conditions. In Figure 5 it will be noted that explosion pressures in the laboratory apparatus range from 72 psi to 35 psi for the vent ratio range from 0.5 to 2.0 sq. ft./100 cu. ft. of volume. The full scale tests using 12 lbs. of cornstarch and factory sash type vents produced defec-

*N. J. Thompson and E. W. Cousins, "A Direct Reading Explosion Effect Gage," Instruments, Vol. 20, No. 4, April 1947.

tions of about 20 units less over the same vent ratio range, that is from 54 to 14 hundredths of an inch. Therefore, for the average industrial conditions, it is reasonable to assume that the deflection of 12-in. brick wall construction will be 20 hundredths of an inch less than the number of pounds per sq. inch of pressure produced in the test apparatus when operated with the same vent ratio.

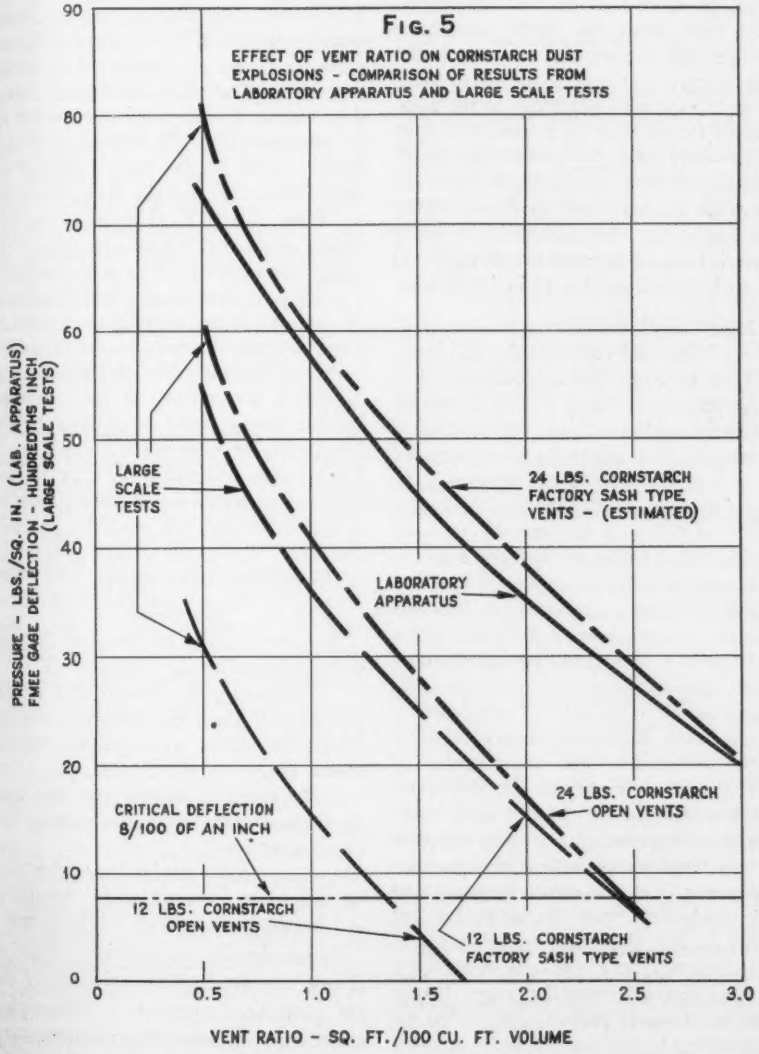


Figure 5. These graphs show the relationship between explosion intensity and vent ratio as secured from both the large scale tests and the laboratory apparatus described in the text.

Similar correlations can be made for the full scale tests with 12 and 24 lbs. of cornstarch using open vents, although open vent conditions are rare in industry.

For more severe than average conditions, an estimation can be made of the vent ratio effect for 24 lb. cornstarch charges with factory sash type vents. Referring again to Figure 5, the added increment of explosion effect due to the addition of factory sash type vents over open vents would place the curve for this condition very slightly above and parallel to the curve for the laboratory apparatus results. Therefore, the conversion can be made directly from psi pressure to hundredths of an inch deflection of a 12-in. brick wall.

Since the ultimate strength of average 12-in. brick wall construction with spans of 16 ft. between rigid supports is reached at approximately 0.08 in. deflection, a barely adequate vent ratio for an average cornstarch dust explosion as determined from Figure 5 is 2.5 sq. ft. per 100 cu. ft. of volume, which is equivalent to about 1 sq. ft. of vent area for each 40 cu. ft. of volume. This compares with the 1 to 50-vent ratio normally recommended for cornstarch handling occupancies. It indicates that the test conditions from which the 1 to 40 ratio is derived may be slightly more severe than has been the actual field experience on which the 1 to 50 recommendation is based. It also emphasizes the safety factor provided by the improbability of producing a truly efficient dust explosion accidentally. The 1 to 50 vent ratio, established by experience, has proven adequate for the majority of industrial cornstarch explosions. Yet it is shown by these tests that a relatively small charge (3 lbs. per 1,000 cu. ft.) when only moderately well dispersed requires a vent ratio of at least 1 to 40 to prevent structural damage. Larger vent ratios would probably be needed for construction lighter than 12-in. brick walls.

It is also possible to estimate from Figure 5 the critical quantity of cornstarch for a 1 to 50-vent ratio; that is, the maximum amount of cornstarch burned in an explosion which would stress 12-in. brick wall construction just to the yield point when a 1 to 50 vent ratio is acting. As mentioned above, reference to Figure 5 shows that the curve for 12 lbs. of cornstarch with factory sash type vents crosses the line of critical deflection at a vent ratio of about 2.5 sq. ft. per 100 cu. ft. of volume. It is estimated that a similar curve crossing the critical deflection line at a vent ratio of 2.0 sq. ft. per 100 cu. ft. of volume (1 to 50) would be that curve produced by an 8 lb. charge of cornstarch. This value is of some assistance in determining just what proportion of a manufacturing space must be filled with a dust cloud in order for a damaging explosion to occur. Eight pounds of cornstarch is about $\frac{1}{6}$ of the maximum amount which could be burned by the oxygen available in the test chamber. It follows that wherever the 1 to 50-vent ratio has provided satisfactory protection in field experience, the explosion probably involved a dust cloud occupying less than $\frac{1}{6}$ the available room volume.

Summary

In summary, the functions of the new dust explosion testing apparatus are:

1. To classify the hazard of a sample dust by evaluating its ventability, dispersibility, ignitibility and explosive concentration range.

2. To simulate directly any dust handling closed equipment by operating as a closed chamber.

3. To predict probable damage to typical industrial construction by correlation of laboratory results with full scale tests.

By broadening the quantity and quality of test information it is hoped to aid the fire protection engineer in determining protective and preventive measures.

New Light on Self-Ignition*

By Nolan D. Mitchell

Chief, Fire Protection Section, National Bureau of Standards

One carload of wood fiberboard burned in transit and eight carloads burned in a warehouse 15 days after shipment, causing $2,609,000 loss. Tests to determine the susceptibility of wood fiberboard to self-heating revealed that the ambient temperature to cause ignition varied inversely with the size of the specimen, ranging from 603°F. for a 1/8-in. cube to 252°F. for an octagonal prism 12-in. thick by 12-in. high and 228°F. for a 22-in. prism. Pronounced self-heating was evident when the surrounding air was held at 147°F.

* * * * *

An untoward event sometimes points the way to useful discoveries. A fire in an Army Warehouse, June 1950†, pointed the way to the subject of this discussion. The story briefly is: On June 2, nine carloads of insulation fiberboard were shipped from a factory in the South, bound for upstate New York. During the afternoon of June 9, in the course of switching, one carload was discovered to be afire and left in the railyard. The other eight cars were sent on a few miles farther to their destination, where they were unloaded into a warehouse during the period June 12 to 15. This lot of eight carloads of fiberboard was stacked in one pile measuring more than 24,000 cubic feet. In the forenoon of June 17, two days afterward, fire was discovered which destroyed the warehouse and its contents. The monetary loss was reported to have been $2,609,000.

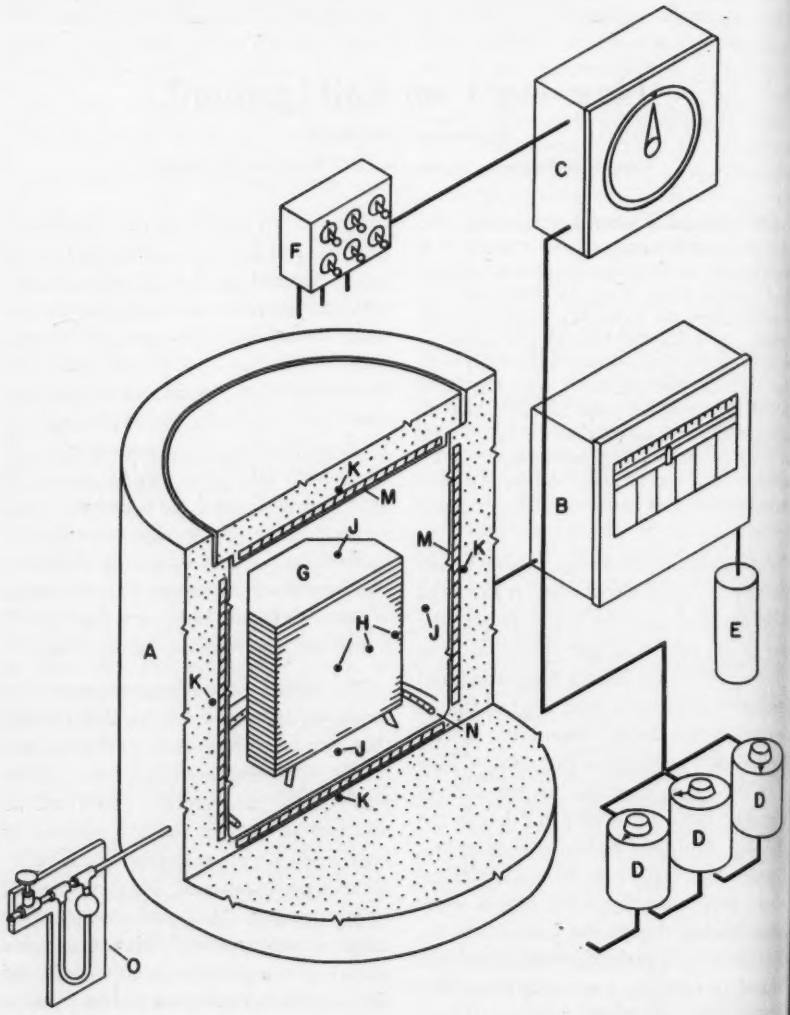
Fires of this nature had been known before, but Bill Nye once remarked that we are all out looking for old, wornout, second-hand experience at the highest market price. An article, "Self-Ignition of Porous Wood Fiberboard,"[1][1] published in Sweden in 1948, discusses what everyone working in the production of porous wood fiberboard has sooner or later experienced: that boards piled after drying do not always cool off. Instead, the temperature may rise within the pile so high that self-ignition results. It has frequently happened that boards which have been loaded directly from the factory have started to burn in transit or in the warehouse of the recipient.

The author of the Swedish paper discusses the heating of dry wood fiberboard that has been dampened and concludes that the total amount of heat that could be produced by this process would not be sufficient to account for the ignition of boards which were at approximately 98°C. (208°F.) when stacked. He experimented by stacking hot boards and measuring the temperatures for several days at four levels in each of two piles, one of dry boards, the other of boards dampened after removal from the dryer to restore a small amount of moisture. The first pile was not ignited, though showing char in 80 hours, whereas the second after 50 hours was ignited to show glow in the center when unstacked.

*Based on a talk presented at the 55th Annual Meeting of the NFPA held in Detroit, Mich., May 7-11, 1951. (Program item No. 65.)

†See Oct. 1950 NFPA *Quarterly*, page 131.

[1] Figures in brackets indicate literature references at the end of this paper.



National Bureau of Standards

Figure 1. Diagrammatic sketch of equipment for tests for spontaneous heating and ignition.

A. Spontaneous heating oven.
B. Potentiometer Recorder.
C. Potentiometer controller.
D. Variable transformers.
E. Cold junction.
F. Thermocouple control switches.
G. Stacked octagonal test sample.
H. Sample thermocouples.
J. Oven temperature thermocouples.
K. Heating element thermocouples.
M. Heating elements.
N. Air distributing ring.
O. Air flow control.

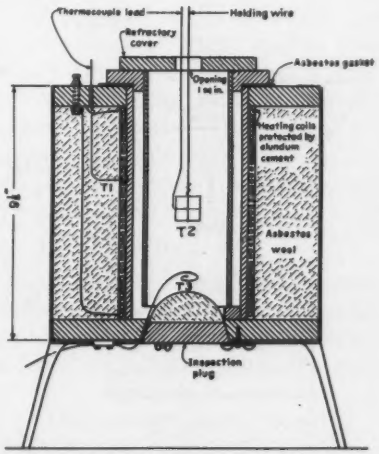
The author suggests that the subject should be studied by the Swedish Wood Research Institute. He concludes the article with this observation:

> "Designers and builders of wallboard dryers should direct their attention to this latest phase of production. As indeed large values are at stake in case of fire, it should be worth while to meet this requirement."

Our military authorities can affirm how right he was, although it is unlikely that either they or the manufacturer of the boards that caused the Voorheesville fire were aware beforehand of this article [1]. On receipt of the report of the warehouse fire, however, some of the fire protection experts of the Corps of Engineers promptly suspected that the fires which had destroyed first the carload of fiberboard in transit and later the great stack in the warehouse were the result of spontaneous ignition [2]. The National Bureau of Standards was asked to determine whether wood fiberboards would self-heat and be ignited. One lot of boards for test was received from a government warehouse, one directly from the factory and another lot was purchased locally. A cane fiberboard and felted purified cotton linters were also tested. The density of the wood fiberboard was 16.8 lb/ft³, the cane fiberboard 17.2 lb/ft³, and the purified cotton linters 21.0 lb/ft³. The moisture content of these materials were, respectively, 4.3, 3.5, and 3.8 percent.

Methods of Test

Three different sets of apparatus were used to study the spontaneous heating characteristics of wood fiberboards. For relatively large specimens cut from the boards, an assembly developed by Mr. A. C. Hutton, known as the controlled oven apparatus, was used (Fig. 1). However, for small specimens, the heated tube furnace (Fig. 2) proved to be more appropriate in size and less time consuming in operation [3]. Later, tests were made in an oven accommodating specimens 22 inches thick.



National Bureau of Standards

Figure 2. Ignition apparatus for solids.
T_1, thermocouple at heating coil.
T_2, thermocouple in air.
T_3, thermocouple in or on specimen.

The controlled oven apparatus was developed for use instead of the relatively insensitive Mackey tester (Fig. 3), which had long been the standard equipment for determining susceptibility of materials to spontaneous heating. Figure 1 also shows a section through the heating chamber of the equipment as well as the arrangement of the controls and potentiometer. The apparatus consists essentially of a 16-in. diameter by 18-in. deep chamber heated by three resistance coils, one on the bottom, one on the side wall, and one on the cover. There are variable transformers for adjusting the current to the coils, an automatic controller, a recording potentiometer and a semi-precision potentiometer. The last can

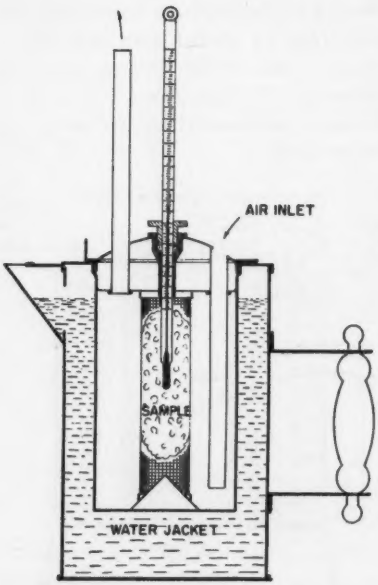


Figure 3. Details of Mackey tester.

be switched successively to the thermocouples to observe more precisely the thermal electromotive forces developed. Dry air, heated to the temperature of the oven, was fed into the bottom of the chamber to rise around the material subjected to test.

Figure 4 is a drawing of a 12-in. thick specimen showing the method of stacking

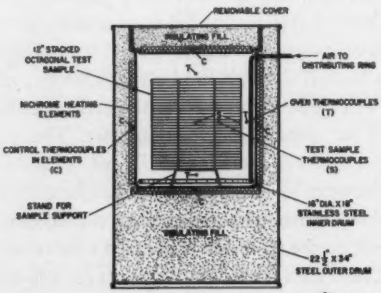


Figure 4. Section through controlled oven showing placement of 12-in. specimen and thermocouples.

the fiberboards. It also shows locations of the thermocouples in the stack and in the ambient air. The boards for the 1-in. and larger specimens were cut to octagonal shape and stacked to depths equal to the width across the flat of the octagon. The ⅛-, ¼-, and ½-in. specimens were cubical. Still smaller specimens were of irregular shape.

The 1-in. and smaller specimens were tested in the heated tube furnace (Fig. 2). This furnace consists of two concentric ceramic tubes, the outer of which is surrounded by resistance coils to supply the heat. The test specimen, with fine wire thermocouples mounted in and on it, was suspended above the thermocouple by which the temperature of the incoming air is measured.

The constant temperature method of test in which the ambient temperature is held at a selected value throughout the test, except as it is affected by the specimen itself after strong self-heating or ignition develops, was used as the principal means for studying the heating characteristics of the fiberboard. The specimen was introduced into the preheated chamber and allowed to remain until the peak of self-heating (evidenced by a rise of the specimen temperature above that of the chamber) was well past, or until the self-heating had continued to ignition. For each of the specimen sizes, except the larger ones, tests were run at different ambient temperatures until the lowest temperature from which ignition would occur, under the conditions of the test, was determined. In most instances, it was possible to judge from preliminary data the approximate range within which this temperature might be expected to lie.

The characteristic pattern of self-heating is clearly indicated in Figures 5 and 6,

Figure 5. Twelve-inch specimen separated at center to show region of initial char.

which show the charred area confined to the central part of the specimens. The vertical section of the 12-in. thick stack, Figure 6, shows how the ignition zone lies in the central portion. Since that region is well insulated by the outer portions of the specimens, the heat produced there is largely confined, and consequently the temperature builds up to ignition most rapidly at the center of the specimen. Ignition by spontaneous heating started at the center of the specimens of all sizes, and unless intentionally stopped as in the case of those shown, spreads outward through the remainder of the material [4].

Results of Tests

IGNITION TESTS: The initial tests were made on the wood fiberboard and included specimens of the 2-, 4-, 8-, and 12-in. sizes. It was found that the larger the specimen

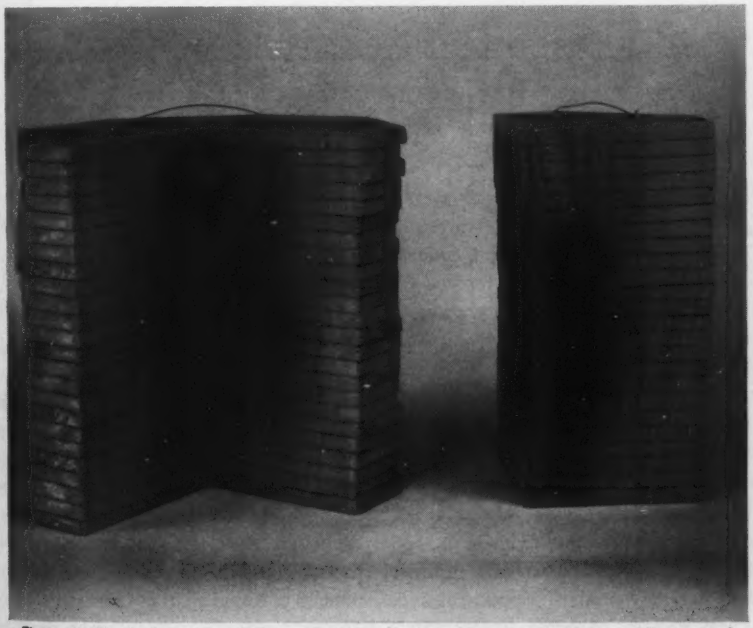


Figure 6. Vertical section of 12-in. specimen showing charred central region after quench.

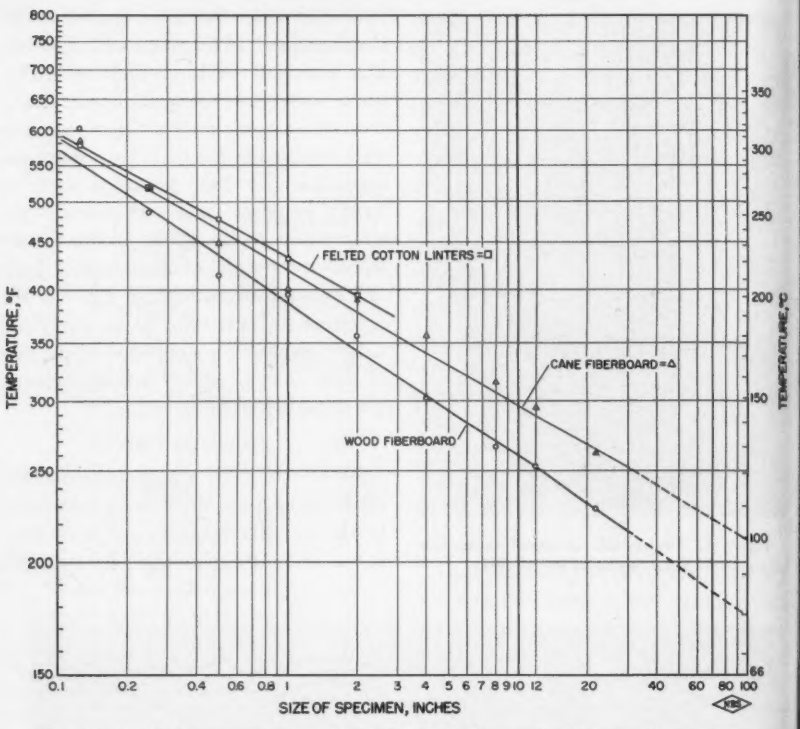


Figure 7. Ambient temperatures causing ignition of fiberboard specimens of various sizes.

the lower the temperature of the ambient air required to cause ignition. The results are plotted to log scale in Figure 7.

The results of the tests of the small specimens in the heated tube furnace extend the line farther up the temperature scale. Specimen 0.01 in. in size required an ambient temperature of 840°F. (449°C.) for ignition. Tests with fiberboards made from sugarcane bagasse gave smiliar results but usually required slightly higher temperatures.

The question then arose: Was this relation between the ignition temperature and size of the specimen characteristic of other fibrous organic materials? Specimens 2 in. and less in size, of felted cotton linters which had been reduced to 96 percent purified alpha cellulose, were found to have similar characteristics but required yet slightly higher temperatures for ignition as shown in Figure 7. They also required a longer time at the constant temperature for ignition.

The results, together with the time required to cause ignition, are given in Table I. For both ignition and non-ignition, the values given are those of the constant temperatures of the air within the chamber. Although the temperatures required to produce ignition do not differ greatly, the time to accomplish this differs markedly. For example, the time to ignite the 1-in.

TABLE I. Summary of Ignition Data

Thickness of Specimen in.	Wood Fiberboard: Highest Non-Ignition Temp. °F	Wood Fiberboard: Lowest Ignition Temp. °F	Wood Fiberboard: Time to Ignition hr.: min.	Cane Fiberboard: Highest Non-Ignition Temp. °F	Cane Fiberboard: Lowest Ignition Temp. °F	Cane Fiberboard: Time to Ignition hr.: min.	Cotton Fiber Felted: Highest Non-Ignition Temp. °F	Cotton Fiber Felted: Lowest Ignition Temp. °F	Cotton Fiber Felted: Time to Ignition hr.: min.
1/8	601	603	....	576	585	0:01	572	579	0:10
1/4	479	486	....	514	518	0:04	509	518	0:40
1/2	413	414	....	442	446	0:14	469	478	4:10
1	388	396	0:18	392	401	0:23	428	432	16:00
2	347	356	0:55	383	390	1:30	...	394	63:00
4	293	302	3:30	352	356	4:00	374*	...	....
8	248	266	14:00	304	315†	....	...	...	....
12	228	252	30:00	282	295	32:00	...	...	....
22	...	228	96:40	...	261	150:00	...	...	....

*This temperature of the ambient air caused 9°F of self-heating. The test was discontinued after 87 hrs. Had the test been continued, ignition might have resulted.

†This specimen had been held in the oven at 304°F for 30 hrs. previous to subjecting it to 315°F. The maximum self-heating at 304°F was 31°F.

specimen of wood fiberboard was 18 minutes and for the 1-in. specimen of cotton linters was 16 hours.

TESTS FOR SELF-HEATING: Tests were also made in the controlled oven apparatus to determine the degree of self-heating developed at temperatures below those at which ignition took place.

A 12-in. specimen when held in air at 147°F. (64°C.) was self-heated to one degree F. above the ambient temperature. With higher ambient temperatures, using

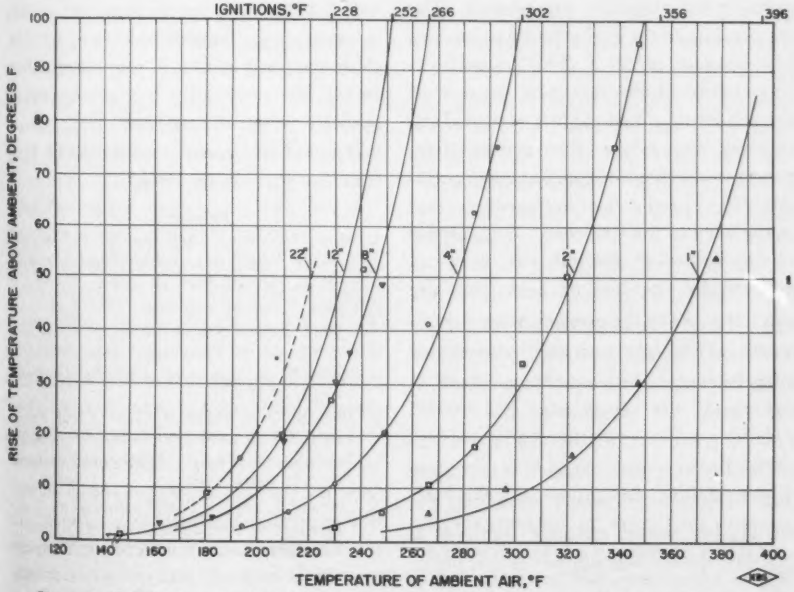


Figure 8. Self-heating produced by ambient air temperatures in various sized specimens of wood fiberboard.

specimens of the same size, the self-heating increased in approximate geometrical ratio as shown by Figure 8. As would be expected, the ambient temperature necessary to produce the minimum self-heating that could be detected in the apparatus was higher when the size of the specimen was smaller. The consistent increase in self-heating with higher ambient temperatures, for a given size of specimen, is also evident. Here, too, the relations are such as to give the set of curves shown. The tests on cane-fiberboards and felted cotton linters gave similar results.

In addition to the tests reported above, exploratory tests of the same nature are in progress on other materials. Thus, shavings of Douglas fir were self-heated to 225°F. (124°C.) when subjected to an ambient temperature of 252°F. (122°C.).

For freshly crushed coal, a somewhat different test procedure was adopted. The temperature of the air in the apparatus was held constant at 194°F. (90°C.) until the temperature of the specimen, because of the self-heating, had slightly exceeded the ambient temperature. The ambient temperature was then increased at appropriate intervals to keep it close to the same as that in the edge of the specimen. The purpose of this follow-up method was to reduce substantially the loss of heat from the specimen. As in the previous tests, the observed self-heating was most pronounced near the center of the specimen, where, at 143 hours, the temperature was 537°F. (280°C.), or 150°F (83°C.) above the ambient temperature. Since it was evident that, using the follow-up procedure, the self-heating would certainly continue to ignition, the test was stopped at that point.

A few tests with alfalfa hay indicated that it, too, is susceptible to self-heating and ignition in the same manner. The hay ignited, under the conditions of the test, at about the same temperature as the cane-fiberboard specimens.

Summary and Discussion

Tests with wood fiber insulating boards, felted purified cotton linters, coal and hay showed that spontaneous heating in appreciable amounts was observable at relatively low ambient temperatures. The larger the volume involved, the lower the temperature required to initiate perceptible self-heating. Likewise, the temperatures required to cause self-ignition of the larger volumes of material were decidedly lower than those required for the self-ignition of the smaller ones. Whereas ambient temperature of 603°F. was required to cause the ignition of a $\frac{1}{8}$-in. cube of wood fiberboard, a specimen 22 in. thick required only 228°F. to ignite it through spontaneous heating. The self-heating of a 12-in. thick specimen at 147°F. was appreciable. In fact, the self-heating was accelerated to ignition when the ambient temperature was raised to prevent undue loss of heat from the reaction so started.

References

1. Bjorn Holmgren, Self-Ignition of Porous Wood Fibreboard, Svensk Papperstidning, V. 51, No. 10, May 31, 1948.
2. Office, Chief of Engineers, Fire Loss Summary, Department of the Army, Fiscal year 1950, (Fire Prevention and Protection Branch Repairs and Utilities Division, April, 1951).
3. Nicholas P. Setchkin, A Method and Apparatus for Determining the Ignition Characteristics of Plastics. NBS Jour. Research 43, 591 (Dec. 1949).
4. Clement R. Brown, The Determination of the Ignition Temperatures of Solid Materials, The Catholic Univ. of America, Washington, D. C.

Fire and Fire Losses Classified, 1950

There were approximately 600,000 building fires in the United States in 1950 causing $699,600,000 damage, according to estimates compiled by the National Fire Protection Association. An additional 1,200,700 fires not involving buildings—aircraft, motor vehicles, forest, ship, rubbish, grass fires, etc.—accounted for an estimated $76,840,000 loss, and increased the number of fires of all types in the United States in 1950 to 1,800,700. The total loss was approximately $776,440,000. Building fire estimates for 1949 reported in the October 1950 *Quarterly*, showed 580,000 fires with loss of $672,500,000. It is interesting to note that the number of fires for 1950 has increased 3.5 per cent over 1949 figures, while the loss of 1950 is 4 per cent more than the previous year. Preliminary estimates by the National Board of Fire Underwriters for the first 8 months of 1951 indicate an increase of approximately 5 per cent over the same period of 1950.

The data from which Tables I to IV were compiled were obtained from sixteen state fire marshals' reports for the year 1950 or the closest fiscal year thereto. Reports of these particular states were chosen because they contained the most complete classification of cause and occupancy data. While the methods of reporting and tabulating fire loss figures differ from state to state, the volume of statistics from these sixteen typical states, representing all sections of the country, and including both primarily agricultural and industrial states, is sufficiently large to indicate the relative distribution of fires and fire losses. Table I shows the number of fires by occupancy in fourteen states and Table II the loss by occupancy in thirteen states. Tables III and IV list the number of fires and loss by cause in sixteen and twelves states respectively. Table V summarizes loss statistics of all states that have furnished data to the NFPA. The fire experience for the states of Nebraska and North Carolina does not appear in Tables I-IV. Reports from these states were received after these tables were assembled.

Tables VI and VII, showing the nationwide distribution of fires and losses by occupancy and causes, are based primarily on typical state experience enumerated in Tables I to IV. Since the value of Table VI increases as the number of items reported is expanded, new classifications have been added from year to year whenever available data permitted. Although no new items could be included this year it is hoped that more detailed reporting of state experience will permit additional occupancies to be reported in the future.

Various sources have furnished figures for certain items in Table VI. Railroad losses were furnished by the Association of American Railroads, Fire Protection and Insurance Section. The 1950 railroad experience shows a 12 per cent increase in the amount of loss, but a 3.5 per cent decrease in the number of fires. Statistics on aircraft fires were compiled by the NFPA Committee on Aviation and Airport Fire Protection. Motor vehicle data are based on a recent survey of 550 U. S. cities (Fire Record of Cities, April 1951 *Quarterly*). Forest fire estimates are those compiled and published by the Forest Service of the U. S. Department of Agriculture in its annual summary of forest fire statistics, which includes the number of forest fires by cause and size, the areas burned and the

Continued on page 178

TABLE I. Number of Fires by Occupancies in Fourteen States — 1950

Occupancies	Connecticut[1]	Illinois[2]	Iowa	Kansas	Louisiana	New Hampshire	Ohio	Oklahoma[2]	Oregon[2]	South Dakota[1]	Texas	Vermont[2,3]	West Virginia[2]	Wisconsin	Total
I. PUBLIC BUILDINGS															
Government buildings	5	3	....	2	....	....	....	....	16	3	....	....	....	13	42
Hospitals, institutions	....	23	10	4	59*d*	2	30	4	....	1	11	3	4	25	176
Schools and colleges	13	65	19	16	62	4	40	16	44	7	45	6	12	111	460
Churches	8	71	23	17	37	5	86	11	27	3	41	3	7	100	439
Theatres, including motion pictures	8	27	19	4	10	....	28	5	19	7	15	3	4	28	177
Amusements, halls	19	84	29	11	....	4	70	....	....	18	3	15	20	86	359
II. RESIDENTIAL															
Hotels	15	328*a*	48	44	350*a*	....	151	124*i*	462*b*	49*i*	85	18	5	140	1,819
Boarding and rooming houses	35	....	9	16	....	35*g*	....	64	....	20	48	1	....	59	287
Apartments	100	2,773*b*	174	103	....	109	1,267*b*	....	....	....	565	5	33	220	5,349
Dwellings	898	5,518	1,598	1,322	3,185	716	5,291	854	9,141*j*	442	3,114	663	523	19,600	52,865
III. MERCANTILE															
Offices and multiple mercantiles	28	175	42	21	363	90	114	13	634	6	92	2	7	76	1,663
Restaurants, taverns	50	403	95	43	....	32	....	....	160	....	213	7	21	640	1,664
Miscellaneous mercantiles	97	1,228	194	245	158	....	607	68	....	133*m*	620	76	87	1,014	4,527
Warehouses	20	106	97	30	87	10	207	22	31	....	56	5	27	135	833
IV. MANUFACTURING															
Metal workers	3	26	28	13	9	5	....	....	44	5	....	1	....	103	237
Woodworkers	5	7	19	3	25	19	....	....	180	....	....	13	3	12	286
Grain mills, elevators	....	144	21	9	11	....	....	....	17	17	6	....	....	74	299
Packing plants	....	....	5	13	....	....	....	....	37	....	10	2	1	....	68
Bakeries	6	36	7	2	....	....	....	....	21	....	....	3	1	18	94
Textile workers	2	....	....	2	42	....	....	....	1	....	....	6	....	7	60
Printing	2	....	11	6	....	....	....	....	9	1	3	1	....	24	57
Laundries	9	36	13	19	....	....	18	14	29*k*	4	32	3	....	22	199
Cleaners, tailors	10	31	9	....	....	3	42	3	....	3	45	1	5*n*	42	194
Miscellaneous manufacturing	61	452	37	21	116	46	494	38	84	11	68	25	31	336	1,820
V. MISCELLANEOUS															
Barns	84	558	186	297*c*	129*c*	64	396	45	300*l*	100	155	262	15	1,032	3,623
Outbuildings	....	1,267	140	....	....	66	401	25	....	24	337	37	10	551	2,858
Lumber and coal yards	2	19	11	1	27	2	77	6	....	2	26	....	....	22	195
Piers, including shipyards	....	15	....	....	....	....	....	....	....	....	....	....	....	....	15
Railroad property, inc. rolling stock	....	119	35	20	27*e*	....	....	....	....	15	....	....	4	145	365
Bulk oil storage, refineries	....	19	....	10	46	....	....	....	29	2	1	....	1	....	108
Garages	119	1,251	316	27	26*f*	42*h*	515*h*	156	48	72*h*	16	24	36	382	3,030
Filling stations	7	100	33	29	....	....	....	15	....	....	34	3	13	85	319
Power plants, pump houses	1	11	13	11	....	....	....	....	35	5	....	....	1	78	155
Creameries and dairies	....	....	6	1	....	....	....	....	11	2	....	3	....	23	46
Miscellaneous structures	221	647	279	15	85	57	1,413	300	34	22	211	5	21	50	3,360
Hangars and contents	....	3	....	1	....	....	....	....	....	....	....	....	....	3	7
VI. OTHER THAN BUILDING FIRES															
Aircraft	....	1	....	2	....	....	....	....	....	....	....	....	....	2	5
Motor vehicles	157	3,073	700	343	532	....	2,711	564	835	149	....	16	33	1,685	10,798
Forest fires	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Rubbish, grass, brush	....	44	33	....	....	....	....	3,946	....	77	....	....	....	57	4,157
Miscellaneous	4	488	8	....	....	....	96	....	....	11	....	36	22	2,521	3,186
Totals	1,989	19,151	4,267	2,723	5,386	1,311	14,054	6,293	12,248	1,211	5,852	1,248	947	29,521	106,201

[1]Fiscal year ends June 30, 1951.
[2]Insured claims only.
[3]No losses less than $50.
a. Includes boarding houses.
b. Includes rooming houses.
c. Includes livestock, hay, growing crops, etc.
d. Includes public buildings.
e. Includes power plants.
f. Includes aircraft hangars.
g. Includes hotels.
h. Includes filling stations.
i. Includes restaurants.
j. Includes apartments.
k. Includes dry cleaners.
l. Includes outbuildings.
m. Includes warehouses.
n. Includes laundries.

[1]Fiscal year ends June 30, 1951.
[2]Insured claims only.
[3]No losses less than $50.
a. Includes boarding houses.
b. Includes rooming houses.
c. Includes livestock, hay, growing crops, etc.
d. Includes public buildings.
e. Includes power plants.
f. Includes aircraft hangars.
g. Includes hotels.
h. Includes filling stations.
i. Includes restaurants.
j. Includes apartments.
k. Includes dry cleaners.
l. Includes outbuildings.
m. Includes warehouses.
n. Includes laundries.

TABLE II. Fire Losses by Occupancies in Thirteen States — 1950

Occupancies	Connecticut[1]	Illinois[2,4]	Iowa	Kansas	Louisiana	New Hampshire	Ohio	Oregon	South Dakota[1]	Texas	Vermont[2,3]	West Virginia[3]	Wisconsin	Total
I. PUBLIC BUILDINGS														
Government buildings	$2,304	$125	.....	$30,010	.....	.....	.....	$13,224	$2,333	.....	.....	.....	$31,726	$79,722
Hospitals, institutions	.....	5,628	148,443	22,385	135,352*d*	$1,555	$24,137	.....	50	$39,238	$594	$128,500	6,843	512,725
Schools and colleges	1,730	829,225	23,162	316,019	318,288	10,540	94,323	360,754	72,549	171,457	8,384	404,301	373,813	2,984,545
Churches	19,062	241,694	248,562	81,985	104,020	2,920	612,735	21,290	15,613	366,054	624	53,584	430,580	2,198,723
Theatres	5,044	102,791	190,075	4,233	25,116	.....	226,954	58,975	79,836	154,960	14,319	222,550	68,666	1,153,519
Amusements, halls	90,188	138,931	334,940	56,548	.....	45,000	347,523	.....	85,437	7,702	21,206	458,749	301,085	1,887,309
II. RESIDENTIAL														
Hotels	23,053	439,224*a*	22,375	777,030	302,982*a*	.....	62,001	256,234*b*	299,472*i*	84,726	68,842	233,700	71,177	2,640,816
Boarding, rooming houses	38,536	.....	4,118	55,259	.....	196,122*g*	.....	.....	24,416	59,501	8,675	.....	28,077	414,704
Apartments	141,475	277,860*b*	405,863	206,870	.....	136,197	832,740*b*	.....	.....	747,867	11,070	179,697	64,908	3,004,547
Dwellings	1,516,156	5,632,860	1,942,493	762,639	2,882,037	593,957	4,271,598	4,022,570*j*	249,719	3,074,435	527,567	1,668,417	4,547,161	31,691,609
III. MERCANTILE														
Offices and multiple mercantiles	290,928	339,169	253,548	8,635	866,822	240,876	238,115	2,609,282	928	280,551	309	93,051	88,644	5,310,858
Restaurants, taverns	103,483	360,845	337,862	50,720	.....	161,498	.....	215,974	.....	827,266	3,633	101,830	664,007	2,827,118
Misc. mercantiles	278,517	1,630,977	1,229,908	977,399	423,949	.....	2,415,042	.....	763,891*m*	3,899,904	476,340	2,234,176	1,949,727	16,279,830
Warehouses	81,248	647,988	472,977	137,761	610,272	29,335	2,397,655	37,560	.....	251,080	21,135	165,418	267,237	5,119,666
IV. MANUFACTURING														
Metal workers	2,700	397,175	244,077	101,892	14,864	1,465	.....	209,618	2,350	.....	253	.....	96,131	1,070,525
Woodworkers	9,988	7,970	35,015	4,650	99,615	57,556	.....	1,892,194	.....	.....	71,742	15,500	105,439	2,299,669
Grain mills, elevators	.....	2,097,674	396,567	339,227	208,539	.....	.....	275,337	383,164	41,785	.....	.....	118,616	3,860,909
Packing plants	.....	.....	3,102	36,368	.....	.....	.....	39,094	.....	72,515	2,520	11,000	.....	164,599
Bakeries	20,048	10,255	17,795	43,000	.....	.....	.....	28,052	.....	.....	542	5,500	23,815	149,007
Textile workers	2,200	.....	.....	17	46,820	.....	.....	466	.....	.....	19,662	.....	25,560	94,725
Printing	9,500	.....	44,150	6,225	.....	.....	.....	2,521	500	9,737	110	.....	4,549	77,292
Laundries	6,418	191,267	44,068	172,442	.....	.....	17,435	22,368*k*	18,768	107,513	15,123	.....	12,798	608,200
Cleaners, tailors	23,725	10,465	7,214	.....	.....	3,900	104,475	.....	7,979	60,178	621	38,101*n*	13,146	269,804
Misc. manufacturing	379,327	2,006,840	275,580	67,164	266,721	98,864	4,703,091	831,525	49,650	648,555	102,282	1,056,348	3,179,739	13,665,686
V. MISCELLANEOUS														
Barns	343,580	3,226,627	849,160	689,766*c*	287,775*c*	176,573	1,938,735	469,094*l*	204,246	147,274	772,932	91,850	1,732,390	10,930,002
Outbuildings	.....	426,029	236,187	.....	.....	177,118	165,431	.....	9,898	225,155	51,267	14,225	229,163	1,534,473
Lumber and coal yards	3,100	59,525	68,100	6,500	42,641	28,000	133,898	.....	83,060	241,537	.....	.....	101,981	768,342
Piers, inc. shipyards	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Railroad property, inc. rolling stock	.....	30,044	259,397	12,967	47,313*e*	.....	.....	.....	59,705	.....	.....	31,250	44,426	485,102
Bulk oil stg., refineries	.....	29,385	.....	35,060	187,035	.....	.....	16,603	1,541	10,000	.....	25,000	.....	304,624
Garages	150,454	811,079	549,581	79,528	67,955*f*	7,200*h*	524,520*h*	79,948	237,269*h*	94,509	98,222	321,257	226,495	3,248,017
Filling stations	3,730	28,155	87,578	38,818	.....	.....	.....	.....	.....	67,382	10,809	19,074	54,005	309,551
Power plants, pump houses	25	212,989	20,748	2,085	.....	.....	.....	117,980	30,965	.....	.....	1,100	87,408	473,300
Creameries and dairies	.....	.....	33,130	50,000	.....	.....	.....	106,674	*324*	.....	59,019	.....	10,425	259,572
Misc'laneous structures	620,714	352,732	425,807	331,322	298,715	121,383	4,817,937	108,060	40,786	545,769	3,143	318,825	39,079	8,024,273
Hangars and contents	.....	88,200	.....	500	.....	.....	.....	.....	.....	.....	.....	.....	9,762	98,462
VI. OTHER THAN BUILDING FIRES														
Aircraft	.....	.....	.....	2,300	.....	.....	.....	.....	.....	.....	.....	.....	1,846	4,146
Motor vehicles	48,578	318,878	83,886	42,708	100,861	.....	465,205	100,589	34,106	.....	8,028	131,080	245,374	1,579,293
Forest fires	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rubbish, grass, brush	.....	8,227	7,279	.....	.....	.....	.....	.....	23,566	.....	.....	.....	7,459	46,531
Miscellaneous	6,050	140,915	351	.....	.....	.....	5,749	.....	6,285	.....	45,183	11,422	395,819	611,774
Totals	$4,221,861	$21,101,748	$9,303,098	$5,550,032	$7,337,692	$2,090,059	$24,399,299	$11,895,986	$2,788,407	$12,236,650	$2,424,156	$8,035,505	$15,659,076	$127,043,569

[1]Fiscal year ends June 30, 1951.
[2]Insured claims only.
[3]No losses less than $50.
[4]Does not include Chicago.
a. Includes boarding houses.
b. Includes rooming houses.
c. Includes livestock, hay, growing crops, etc.
d. Includes public buildings.
e. Includes power plants.
f. Includes aircraft hangars.
g. Includes hotels.
h. Includes filling stations.
i. Includes restaurants.
j. Includes apartments.
k. Includes dry cleaners.
l. Includes outbuildings.
m. Includes warehouses.
n. Includes laundries.

TABLE III. Number of Fires by Causes in Sixteen States — 1950

Causes	Connecticut[1]	Illinois[1]	Iowa	Kansas	Louisiana	Michigan	New Hampshire	Ohio	Oklahoma[2]	Oregon	Rhode Island[4]	South Dakota[1]	Texas	Vermont[2,3]	West Virginia[2]	Wisconsin	Total
Chimneys, flues, defective or overheated	88	900	263	98	88	2,674	196	709	34	679	53	82	86	124	64	1,510	7,648
Sparks on roof	29	513	216	36	14	1,086	....	....	....	224	....	....	25	7	....	....	2,150
Defective or overheated heating equipment	166	1,396	286	200	337	2,895	83*b*	1,214	96	1,840	146	162	224	95	72	2,621	11,833
Rubbish	100	2,225	290	215	97	11,151	27	458	4,588	11	50	66	272	12	12	357	19,931
Combustibles near heaters	6*a*	....	21	....	....	....	....	....	....	....	....	....	334	....	34	398	793
Open lights, flames, sparks	14	312	49	59	50	291	10	857	....	213	56	79	41	20	20	1,208	3,279
Hot ashes, coals	13	226	39	21	95	230	4	116	....	893	2	8	....	22	4	147	1,820
Smoking and matches	281	3,543	465	236	768	3,978	165	2,512	237	3,269	131	108	927	114	59	5,045	21,838
Children and matches	74	....	100	....	....	1,336	34	535	100	....	23	26	227	15	28	358	2,856
Electrical, fixed service, fires due to misuse, or faulty wiring and equipment	185	3,542	251	317	738	1,950	109	2,545	163	1,213	86	127	662	90	106	2,052	14,136
Electrical, power consuming appliances	89	252	205	16	61	1,733	35	407	41	672*d*	....	33	125	....	24	1,472	5,165
Flammable liquids, misc. including home dry cleaning and starting fire with	18	1,195	58	126	313	379	13	766	114	250	4	14	295	137	58	86	3,826
Torches, welding, cutting, plumbers, etc.	11	....	77	....	....	....	14	99	7	....	....	21	....	....	7	130	366
Lamps, lanterns, oil stoves	54	....	176	....	....	2,805	197	....	12	....	31*f*	53	72	....	4	877	4,281
Gas and explosions	....	139	189	35	98	406	11	229	75	....	....	16	421	2	....	175	1,796
Grease, tar, etc.	22	224	64	43	112	....	59	194	....	910	16	12	143	38	10	909	2,756
Spontaneous ignition	66	414	115	15	43	5,062	34	270	92*c*	109	15	27	76	12	12	251	6,613
Lightning	44	393	71	63	228	613	76	151	9	93	9	44	90	60	7	9,695	11,646
Thawing pipes	5	....	20	....	....	173	5	....	....	129	....	....	12	....	5	19	368
Sparks from machinery, friction	....	73	16	1	34	....	....	....	....	49	....	1	....	10	....	51	235
Incendiary, suspicious	48	70	13	10	35	387	28	137	....	45	20	6	69	12	43	128	1,051
Miscellaneous	409	1,075	505	152	239	9,588	49	1,543	503	1,352	38	101	318	79	24	304	16,279
Unknown	210	1,902	566	870	1,564	3,297	102	1,053	222	37	351	116	929	273	267	1,033	12,794
Explosions	24	163	24	54	120	....	1	....	....	260*e*	....	19	28	7	7	402	1,109
Exposure	33	594	188	156	352	1,005	59	259	....	....	35	88	476	119	80	293	3,737
Totals	1,989	19,151	4,267	2,723	5,386	51,039	1,311	14,054	6,293	12,248	1,066	1,211	5,852	1,248	947	29,521	158,306

[1]Fiscal year ends June 30, 1951.
[2]Insured claims only.
[3]No losses less than $50.
[4]Fiscal year ends September 30, 1950.

a. Includes clothes on light bulbs.
b. Includes oil hot water heaters.
c. Includes friction.
d. Includes hot metals.
e. Includes sparks from combustion.
f. Includes gas stoves.

e. Includes sparks from combustion.
f. Includes gas stoves.

TABLE IV. Fire Losses by Causes in Twelve States — 1950

Causes	Connecticut[1]	Illinois[1,4]	Iowa	Kansas	Louisiana	Ohio	Oregon	South Dakota[1]	Texas	Vermont[2,3]	West Virginia[2]	Wisconsin	Total
Chimneys, flues, defective or overheated	$720,235	$876,211	$331,669	$95,265	$50,332	$660,050	$501,617	$62,260	$115,817	$108,563	$204,101	$623,943	$4,350,063
Sparks on roof	30,784	681,069	137,512	42,675	4,812	.....	199,149	.....	16,273	14,908	.....	.....	1,127,182
Defective or overheated heating equipment	254,174	1,050,696	810,191	160,828	344,834	3,110,766	987,022	302,647	225,343	77,830	422,059	1,138,903	8,885,293
Rubbish	65,555	203,506	184,258	33,969	62,548	270,903	1,687	36,838	408,750	2,574	33,225	181,566	1,485,379
Combustibles near heaters	70,905*a*	.....	9,549	.....	.....	.....	.....	.....	273,195	.....	82,822	67,685	504,156
Open lights, flames, sparks	15,580	184,385	99,356	41,287	38,492	533,584	24,414	58,017	98,646	39,946	51,230	649,178	1,834,115
Hot ashes, coals	56,459	72,243	29,430	7,151	94,917	144,396	250,487	2,147	.....	26,859	3,075	57,308	744,472
Smoking and matches	563,850	362,450	392,818	75,770	238,632	1,304,931	808,627	31,458	1,138,091	28,244	633,973	798,642	6,377,486
Children and matches	97,061	.....	39,829	.....	.....	349,566	.....	21,339	146,826	26,616	58,252	149,981	889,470
Electrical, fixed service, fires due to misuse, or faulty wiring and equipment	467,367	3,515,011	738,002	330,901	912,328	2,765,498	2,018,222	205,454	1,614,186	159,032	720,551	4,280,616	17,727,168
Electrical, power consuming appliances	128,201	134,832	193,847	8,767	48,406	443,422	352,420*b*	143,897	241,289	.....	134,217	541,262	2,370,560
Flammable liquids, misc. including home dry cleaning and starting fires with	5,407	1,252,287	82,926	75,136	274,941	505,846	287,173	11,905	460,299	138,148	227,622	68,684	3,390,374
Torches, welding, cutting, plumbers, etc.	6,609	.....	90,629	.....	.....	138,791	.....	32,081	.....	.....	111,710	61,422	441,242
Lamps, lanterns, oil stoves	66,092	.....	158,483	.....	.....	.....	.....	72,534	71,214	.....	5,200	634,542	1,008,065
Gas and explosions	.....	90,228	418,480	43,087	69,894	1,173,380	.....	12,498	688,522	1,004	.....	135,783	2,632,876
Grease, tar, etc.	14,506	45,309	16,878	13,615	21,058	273,129	128,225	40,816	88,945	10,680	7,480	127,636	788,277
Spontaneous ignition	175,693	630,693	304,527	26,713	38,356	1,303,714	183,642	129,612	208,258	34,215	204,875	1,196,039	4,436,337
Lightning	97,117	2,195,000	278,899	162,393	106,584	336,210	42,730	40,125	76,134	53,205	8,601	1,401,176	4,798,174
Thawing pipes	1,104	.....	30,611	.....	.....	.....	386,155	.....	24,133	.....	2,503	32,789	477,295
Sparks from machinery, friction	.....	171,948	27,129	160	33,781	.....	217,301	200	.....	50,141	.....	75,544	576,204
Incendiary, suspicious	57,604	113,083	25,426	28,835	39,839	681,629	23,983	12,323	163,081	218,944	383,004	1,040,020	2,787,771
Miscellaneous	742,059	224,061	847,970	95,969	283,681	2,019,571	5,028,352	106,528	349,931	141,094	212,370	180,772	10,232,355
Unknown	408,794	8,264,270	3,328,625	4,118,970	4,045,298	7,867,403	61,052	867,977	5,049,504	1,103,117	3,904,588	1,654,170	40,673,768
Explosions	137,508	523,635	118,963	46,456	235,746	.....	393,728*c*	46,837	21,477	1,869	86,976	219,489	1,832,684
Exposure	39,198	510,831	607,091	142,085	393,213	516,510	.....	550,914	756,738	179,139	537,071	341,926	4,574,716
Totals	$4,221,861	$21,101,748	$9,303,098	$5,550,032	$7,337,692	$24,399,299	$11,895,986	$2,788,407	$12,236,650	$2,416,128*d*	$8,035,505	$15,659,076	$124,945,482

[1]Fiscal year ends June 30, 1951.
[2]Insured claims only.
[3]No losses less than $50.
[4]Does not include Chicago.

a. Includes clothes on light bulbs.
b. Includes hot metals.
c. Includes sparks from combustion.
d. Motor vehicle fires not included.

estimated damage. Results of a recent survey of U. S. cities were also the basis for an estimate of the number of rubbish, grass and brush fire. The 1950 estimate of 766,000 represents a 1.5 per cent increase over 1949.

As will be seen in Table V, the eighteen states with a population of 56,645,836 reported a total of 168,816 fires. Experience indicates that this is somewhat under half the actual number of fires. Many states, for example, do not report fires with losses of less than $25 to $50. To obtain a more nearly accurate estimate of the number of fires in these eighteen states, therefore, 100 per cent is added. Making use of this figure and the population ratio, the number of building fires for the nation has been calculated.

To obtain the estimated national fire loss, the population ratio was applied to the loss of the reporting states. To account for losses not reported through the usual channels, 33 1/3 per cent was added as in the previous years. Further adjustment was necessary in a few instances because of unusually large property damage in individual fires.

Table V. Fires per 1000 Population and Fire Loss per Person for Eighteen States, 1950, as Reported by Fire Marshals

State	Population 1950 Census	No. of Fires	Fires per 1000 Pop.	Fire Loss	Fire Loss per Person
Connecticut[1]	1,995,263	1,989	.99	$4,221,862	$2.11
Illinois[2]	8,684,513	19,151	2.21	21,101,748[6]	4.16
Iowa	2,612,598	4,267	1.64	9,303,098	3.57
Kansas	1,894,390	2,723	1.44	5,550,032	2.93
Louisiana	2,667,022	5,386	2.02	7,337,692	2.75
Michigan	6,308,794	51,039	8.10	24,964,346	3.96
Nebraska	1,318,079	2,052	1.54	4,587,408	3.48
New Hampshire[3]	592,880	1,311	2.22	4,251,038	7.20
North Carolina	4,038,814	8,458	2.10	12,106,685	3.01
Ohio	7,899,095	14,054	1.78	24,399,299	3.09
Oklahoma	2,223,650	6,293	2.83	1,398,872	.63
Oregon	1,512,100	12,248	8.10	11,895,986	7.85
Rhode Island[5]	779,931	1,066	1.37	1,862,073[7]	2.39
South Dakota[1]	650,029	1,211	1.87	2,788,407	4.30
Texas[2]	7,672,432	5,852	.76	12,236,651	1.60
Vermont[3,4]	375,833	1,248	3.33	2,424,156	6.45
West Virginia[4]	1,999,097	947	.47	8,035,505	4.02
Wisconsin[3]	3,421,316	29,521	8.64	15,659,076	3.98
Totals	56,645,836	168,816	2.97	$162,786,734	$2.87

[1]Fiscal year ends June 30, 1950.
[2]Building and contents losses only.
[3]Insured claims only.
[4]No losses less than $50.
[5]Fiscal year ends September 30, 1950.
[6]Does not include Chicago losses.
[7]Includes loss from 781 unclassified fires.

States Reporting Partial Data (Not Included in Tabulations)

State	Population	No. of Fires	Fire Loss	Fire Loss per Person
Delaware[1]	316,609	....	2,469,567[3]	7.80
Idaho[1,2]	585,092	....	3,191,147	5.45
Maine[1]	910,456	....	651,582[3]	.72
Maryland	2,324,243	....	3,493,644	1.50
Nevada	158,283	....	1,711,228	10.83
New Mexico[1]	677,152	....	1,412,861	2.09
New York	14,804,118	....	54,052,176	3.65
Utah[1]	686,797	....	1,721,417[3]	2.51

[1]Insured losses only.
[2]Fiscal year ends June 30, 1950.
[3]Net losses paid.

Table VI. Estimated Distribution of U. S. Fire Losses by Occupancies, 1950

These estimated figures are intended to show the relative order of magnitude of fire losses by occupancies, and while they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class. As explained in the text, 100 per cent has been added in estimating the number of fires, and 33 1/3 per cent has been added to the losses to cover unreported losses.

	No. of Fires		Losses	
I. PUBLIC BUILDINGS				
Government buildings	700		$1,200,000	
Hospitals, institutions	1,500		2,200,000	
Schools, colleges	2,900		17,000,000	
Churches	3,100		10,000,000	
Theatres, including motion pictures	1,100		5,300,000	
Amusement, halls	2,700	12,000	5,000,000	$40,700,000
II. RESIDENTIAL				
Hotels	11,500		5,500,000	
Boarding and rooming houses	14,000		8,000,000	
Apartments	51,500		16,000,000	
Dwellings	310,000	387,000	188,700,000	218,200,000
III. MERCANTILE				
Offices and multiple mercantiles	10,400		18,000,000	
Restaurants, taverns	14,800		25,000,000	
Miscellaneous mercantiles	28,800		62,000,000	
Warehouses	5,300	59,300	23,000,000	128,000,000
IV. MANUFACTURING				
Metal workers	2,800		13,500,000	
Woodworkers	3,100		21,000,000	
Grain mills, elevators	2,800		28,000,000	
Packing plants	1,200		8,000,000	
Bakeries	1,100		1,600,000	
Textile workers	4,700		7,000,000	
Printing	800		1,500,000	
Laundries	1,500		2,500,000	
Cleaners, tailors	2,500		2,650,000	
Miscellaneous manufacturing	11,500	32,000	70,000,000	155,750,000
V. MISCELLANEOUS				
Barns	23,000		41,000,000	
Outbuildings	28,000		9,000,000	
Lumber and coal yards	1,400		8,500,000	
Piers, including shipyards	1,600		10,000,000	
Railroad property, inc. rolling stock	4,700		8,750,000	
Bulk oil storage, refineries	1,200		12,000,000	
Garages	19,000		17,000,000	
Filling stations	2,800		2,500,000	
Power plants, pump houses	1,700		5,000,000	
Creameries and dairies	1,200		3,000,000	
Miscellaneous structures	25,000		35,200,000	
Hangars and contents	100	109,700	5,000,000	156,950,000
TOTAL (BUILDING FIRES)		600,000		$699,600,000
VI. OTHER THAN BUILDING FIRES				
Aircraft	300		15,000,000	
Motor vehicles	197,000		9,450,000	
Forest fires	208,400		47,190,000	
Rubbish, grass, brush	766,000		.....	
Miscellaneous	29,000	1,800,000	5,200,000	76,840,000
GRAND TOTAL		2,400,700		$776,440,000

Table VII. Estimated Distribution of U. S. Building Fire Losses by Causes, 1950

These estimated figures are intended to show the relative order of magnitude of fire losses by occupancies, and while they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class.

	No. of Fires	Losses
Chimneys, flues—defective or overheated	29,000	$23,600,000
Sparks on roof	18,000	12,000,000
Defective or overheated heating equipment	45,000	48,200,000
Rubbish	35,600	8,100,000
Combustibles near heaters	8,700	8,500,000
Open lights, flames, sparks	18,000	12,000,000
Hot ashes, coals	8,600	10,000,000
Smoking and matches	93,000	55,000,000
Children and matches	20,200	6,900,000
Electrical, fixed services, fires due to misuse, or faulty wiring and equipment	53,700	73,000,000
Electrical power consuming appliances	20,100	11,500,000
Flammable liquids, misc., including home dry cleaning and starting fires with	14,600	21,000,000
Torches, welding, cutting, plumbers, etc.	4,000	5,500,000
Lamps, lanterns, oil stoves	30,700	30,000,000
Gas and appliances	7,800	9,000,000
Grease, tar, etc.	12,500	5,000,000
Spontaneous ignition	15,000	24,000,000
Lightning	31,000	30,000,000
Thawing pipes	2,700	5,100,000
Sparks from machinery, friction	2,100	6,200,000
Incendiary, suspicious	5,600	15,100,000
Miscellaneous	52,000	20,000,000
Unknown	48,500	215,000,000
Explosions	8,300	19,100,000
Exposure	15,300	25,800,000
TOTAL	600,000	$699,600,000

Index to Advertisers

	Page
Acme Fire Alarm Company, Inc.	A2
Ætna Life Affiliated Companies	A3
American District Telegraph Company	A1
Ansul Chemical Company	A9
"Automatic" Sprinkler Corporation of America	A36
Blaw-Knox Company	A13
Cardox Corporation	*Inside Front Cover*
Central Station Signals, Inc.	A4
Certain-Teed Products Corporation	A17
Chicago Bridge & Iron Company	A5
C-O-Two Fire Equipment Company	A6
Fenwal, Incorporated	A7
Gamewell Company	*Inside Back Cover*
Globe Automatic Sprinkler Company	A8
Grinnell Company	*Back Cover*
Gustin-Bacon Manufacturing Company	A10
Wm. E. Hooper and Sons	A11
Walter Kidde & Company	A15
Kinnear Manufacturing Company	A12
M & H Valve & Fittings Company	A14
R. C. Mahon Company	A21
Mississippi Glass Company	A16
National Fire Protection Association	A22
National Foam System, Inc.	A25
Owens-Corning Fiberglas Corporation	A19
Pittsburgh-DesMoines Steel Company	A18
Pyrene Manufacturing Company	A20
Randolph Laboratories, Inc.	A23
Reliable Automatic Sprinkler Company	A29
Rockwod Sprinkler Company	A24
Safe Manufacturers National Association	A26
Shand and Jurs Company	A28
Star Sprinkler Corporation	A32
Tokheim Oil Tank and Pump Company	A27
United States Plywood Corporation	A31
Van-Packer Corporation	A33
Vapor Recovery Systems Company	A34
Viking Corporation	A35
Vonnegut Hardware Company, Von Duprin Division	A30

EIGHT BRANCH STORES OF FRANKLIN SIMON PROTECTED *Automatically* BY ADT

Thoroughly up-to-date in every respect, eight branch stores of Franklin Simon, one of New York's leading specialty shops, are protected against fire and burglary by ADT Central Station AUTOMATIC Protection Services. The services include: ADT Central Station Burglar Alarm, ADT Sprinkler Supervisory and Waterflow Alarm and Aero Automatic Fire Alarm Services. These and other ADT AUTOMATIC Services are used by thousands of business concerns throughout the United States for better protection at lower cost.

Write for complete information.

ADT

Controlled Companies of
AMERICAN DISTRICT TELEGRAPH COMPANY
155 Sixth Avenue • • New York 13, N. Y.
CENTRAL STATIONS IN ALL PRINCIPAL CITIES

We engineer, design and manufacture:

Interior Fire Alarm Signaling Systems.

Automatic Heat Actuated Fire Alarm Signaling Systems.

Standpipe Fire Line Control and Signaling Systems.

Central Office Systems for Manual Fire, Automatic Heat Actuated Fire Alarm Systems, Sprinkler Alarm and Supervision, Watch Patrol Recording and Kindred Systems.

Supervisory Systems for Detecting Excessive Heat, Pressure and Low Voltage in Transformer Sub-stations and to Automatically Disconnect the Sub-stations from the Line and Load Sides of the Systems.

Local Sprinkler Alarm and Supervisory Systems.

Smoke and Heat Detecting Systems for Air Conditioning Systems.

Sprinkler Waterflow Detectors.

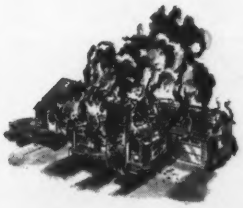
120 Volt A.C. Vibrating Bells.

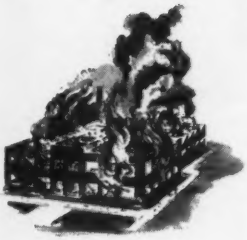
Emergency Switches to Shut Down Fuel Oil Systems, Ammonia Compressors and Air Conditioning Systems.

Ground Detector Systems for Hospital Operating Rooms.

ACME FIRE ALARM CO., Inc.

106 SEVENTH AVE., NEW YORK CITY, N. Y.





Policyholders' Premiums Burning

Mr. AGENT: A FIRE stops your Premium Income on the Property Destroyed until it can be rebuilt. Not only are your policyholders' fire insurance premiums lost for the time being, but many other forms of coverage would have to be cancelled after the property is destroyed.

As an agent, make fire prevention an important part of your activity during the ENTIRE YEAR, not just during Fire Prevention Week. You have a veritable arsenal of ammunition to draw upon — motion pictures, posters, prepared talks and booklets — these are all available through our companies, and also the National Board of Fire Underwriters, the National Fire Protection Association, and the National Association of Insurance Agents.

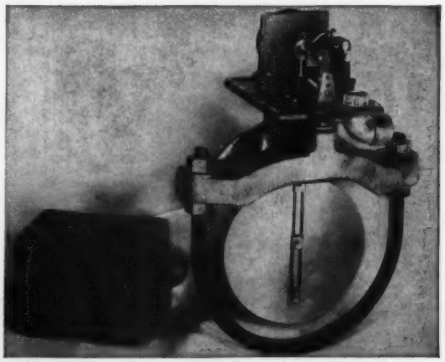
Fire prevention work is one of the most rewarding activities you can undertake. It attracts community-wide attention, good will, and recognition to you and your business. It gives you the satisfaction that comes from performing a worthwhile public service. Its success helps to prevent interruptions to your insurance income, which occur just as soon as insurable property is destroyed.

AUTOMOBILE INSURANCE COMPANY
STANDARD FIRE INSURANCE COMPANY
FIRE AND MARINE UNDERWRITERS

HARTFORD 15, CONNECTICUT

Fire and Marine Insurance — All Forms

Affiliated with
ÆTNA LIFE INSURANCE CO. • ÆTNA CASUALTY AND SURETY CO.



5-inch size shown above. To install simply drill hole in pipe.

CENTRAL STATION SIGNALS, INC. Model PRS

Waterflow Alarm Device is approved by both the Factory Mutual Laboratories and Underwriters' Laboratories, Inc. In hundreds of installations it has proved to be the ideal alarm device for sprinkler systems.

SAVE VITAL MATERIALS! Install this water flow alarm device in place of bulky alarm valves. Only 10 oz. of vital material used in our water flow switch.

- **Made in all sizes from 2½" to 8"**
- **It is positive in operation**
- **Has instantly recycling pneumatic retarding device which prevents false alarms**
- **Has enclosed electrical contacts for 15 amp, 125 volts AC and ½ amp, 125 volts DC**

By installing this most economical alarm device, you will know instantly where the water is flowing. Many plants are having them installed on each floor or in each section. They save water damage.

This device can also be obtained as Model PRT, a coded waterflow transmitter from which signals are received on a punch register and single stroke gong. Practically any number can be installed on a two-wire system, thus resulting in considerable savings on wiring.

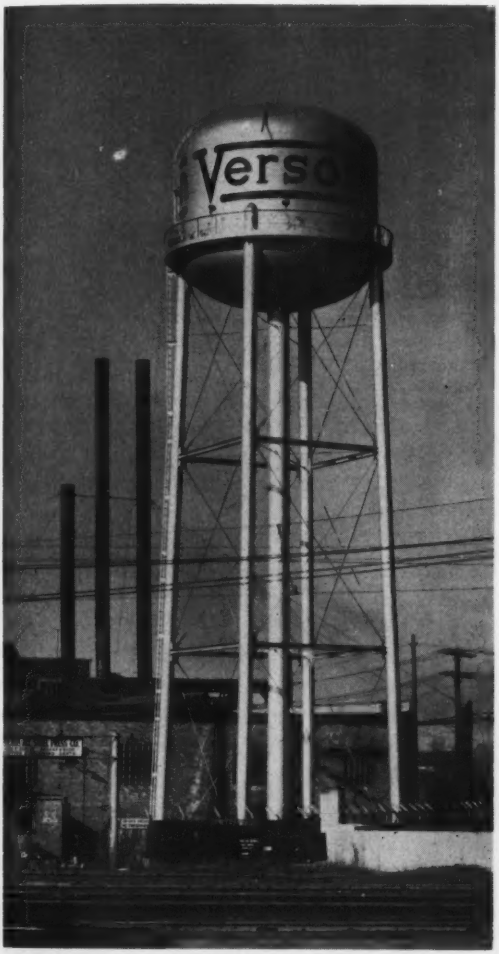
WE SOLICIT YOUR INQUIRIES

CENTRAL STATION SIGNALS, INC.

Manufacturers of all kinds of approved devices used in Central Station Systems or Class 'A' or Class 'B' Proprietary Fire Alarm Systems, either automatic or manual.

71 WEST 23rd STREET -:- NEW YORK 10, N. Y.

INSURANCE COSTS REDUCED



by installation of Horton Elevated Tank

The installation of an automatic sprinkler system and a gravity water tank at the Verson Allsteel Press Company plant in Chicago has reduced insurance costs $26,000 per year.

The Verson plant in Chicago consists of five buildings covering eight acres and containing 350,000 sq. ft. of floor area. The automatic sprinkler system, which was installed by P. Nacey Co., Inc., has 1600 heads and covers 90 per cent of the floor space.

A 100,000-gal. Horton elevated steel tank, 80-ft. to bottom, provides the primary water supply for the sprinkler system and the city water mains are the secondary source.

CHICAGO BRIDGE & IRON COMPANY

CLEVELAND	CHICAGO	BIRMINGHAM	NEW YORK
HAVANA	DETROIT	ATLANTA	PHILADELPHIA
HOUSTON	TULSA	LOS ANGELES	SAN FRANCISCO
SEATTLE	BOSTON	WASHINGTON	SALT LAKE CITY

Plants at Chicago, Birmingham, Salt Lake City and Greenville, Pa.

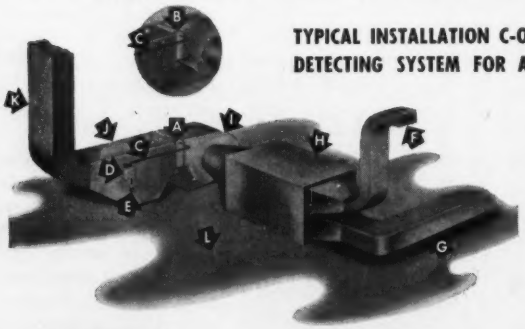
New, Fast-Acting, Automatic "SMOKE-FIRE DETECTIVE" For Air Conditioning

Smoke in your air conditioning spreads fast . . . causes panic, extensive spoilage and needless expense . . . now all can be avoided by installing a modern, fully approved C-O-TWO Automatic Smoke Detecting System.

Smoke, smoldering and fire are spotted in the incipient stage anywhere throughout the air conditioning ducts, as well as via the return air from air conditioned spaces. Four types of smoke detectors and several different installation arrangements are available to fit your particular needs . . . for small air conditioning units, for large air conditioning systems, and whether with or without electrostatic precipitators. All C-O-TWO Automatic Smoke Detecting Systems function by drawing continuous air samples through simple piping to a smoke detector. The first trace of smoke sets off an alarm, based on an exclusive operating principle . . . no chance of smoke spreading . . . the air conditioning instantly shuts down, dampers close and fire extinguishing systems actuate.

Act now for complete free information and descriptive literature on this newest contribution to modern fire fighting. An expert C-O-TWO Fire Protection Engineer will be glad to help you in planning up-to-date, economical, fully approved fire protection facilities for your air conditioning without obligation.

(Special assistance rendered to qualified air conditioning contractors.)



TYPICAL INSTALLATION C-O-TWO AUTOMATIC SMOKE DETECTING SYSTEM FOR AIR CONDITIONING DUCTS

A perforated smoke accumulating pipe
B smoke accumulating pitot tube (alternate)
C pipe line for carrying continuous air samples to smoke detector
D smoke detector
E audible alarm
F fresh air intake and duct
G return air duct
H air cleaning unit
I air fan
J air cooling and heating unit
K supply air duct
L floor level

C-O-TWO

C-O-TWO FIRE EQUIPMENT COMPANY

NEWARK 1 • NEW JERSEY

Sales and Service in the Principal Cities of United States and Canada

Affiliated with Pyrene Manufacturing Company

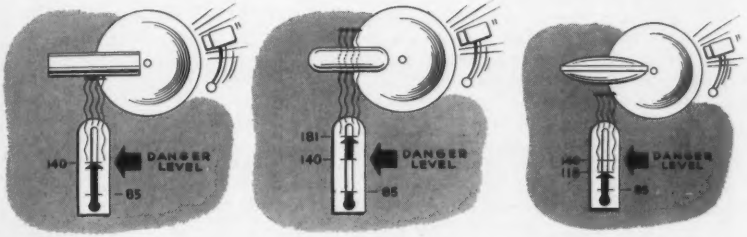
MANUFACTURERS OF APPROVED FIRE PROTECTION EQUIPMENT

Squeez-Grip Carbon Dioxide Type Fire Extinguishers • Dry Chemical Type Fire Extinguishers
Built-In High Pressure and Low Pressure Carbon Dioxide Type Fire Extinguishing Systems
Built-In Smoke and Heat Fire Detecting Systems

Rate Compensation

A New Principle of Fire Detection

Fenwal DETECT-A-FIRE horizontal mount combines unique operation with smart design.



THE SHELL REACTS!

Fenwal DETECT-A-FIRE unit, activated by its temperature sensitive shell, responds *only* when the *temperature of the surrounding air* reaches predetermined danger level.

Do Away With...

TIME LAG

In fixed temperature detection the air temperature rises well above the danger level because of time needed for the device to absorb heat before responding.

FALSE ALARMS

In rate-of-rise type detectors calibrated to operate at a predetermined rate of temperature rise, false alarms may occur even under non-fire conditions.

New RATE-COMPENSATION principle assures positive fire detection for plants, ships, institutions, all commercial, mercantile and public buildings. FENWAL, INCORPORATED, *Temperature Control Engineers*, 1410 Pleasant Street, Ashland, Mass., 111 South Burlington Avenue, Los Angeles 4, Cal.

Visit our Booth 603 at the Chemical Industries Exposition, Grand Central Palace, New York

Fenwal **DETECT-A-FIRE** *Precise, DYNAMIC Fire Detection*

SOMETHING THAT PAYS OFF

All Fires Are Extinguishable. GLOBE protection controls the *FIRE* menace, and places *"strictly preventable," "partly preventable"* and *"cause unknown" FIRES* all in the one class... *extinguishable.* Install GLOBE Sprinklers now.

GLOBE AUTOMATIC SPRINKLER CO.

NEW YORK... CHICAGO... PHILADELPHIA

Offices in nearly all principal cities

THEY PAY FOR THEMSELVES

ASK ANY QUALIFIED
AND IMPARTIAL AUTHORI... ...L TELL YOU . . .

YOUR *BEST* PROTECTION
FOR FLAMMABLE LIQUID, GAS AND ELECTRICAL FIRES

ANSUL
DRY CHEMICAL
FIRE EXTINGUISHING EQUIPMENT

You, who have seen or used an Ansul Dry Chemical Extinguisher at a fire demonstration or on an actual fire, quickly recognized its superior fire-fighting capabilities. Further investigation proves that Ansul "Water-tight Construction" provides greater dependability under severe exposure conditions.

Fire Chiefs, insurance inspectors, safety engineers, etc. recognize Ansul as the leader in the dry chemical extinguisher field. Ansul Fire Extinguishing Equipment and *"PLUS-FIFTY"* Dry Chemical have set unparalleled standards of quality for the fire extinguisher industry.

You get *complete* dry chemical fire protection only from Ansul. There is an Ansul Dry Chemical Fire Extinguisher of the proper size for almost every flammable liquid, gas and electrical fire hazard.

Safeguard your plant and irreplaceable equipment with the *BEST* fire extinguishing equipment available. Protect them with ANSUL EXTINGUISHERS.

ANSUL
MODEL 20-B

ANSUL EXCLUSIVE FEATURES

- Patented Nozzle assures most effective stream pattern . . . Best results by inexperienced operators.
- Special packings in Nozzle and other parts exclude water.
- Corrosion resistant construction throughout.
- Easy on-the-spot Recharging (No tools needed).
- Quick, *positive* puncture operation.
- Special guard protects cartridge . . . rugged construction throughout.
- Ansul *"PLUS-FIFTY"*® Dry Chemical used exclusively.
- Field tested by thousands of satisfied customers.
- Ansul LT Models are the only dry chemical extinguishers listed by U.L. for operation at –65° F.

● Send for File No. 713. You will receive a variety of helpful printed matter. Included is our latest catalog which describes Ansul Extinguishers of all sizes — from the small Ansul Model 4 to Ansul Piped Systems and Ansul 2000 lb. Stationary Units.

ANSUL
CHEMICAL COMPANY
Fire Extinguisher Division
MARINETTE • WISCONSIN

DISTRIBUTORS IN ALL PRINCIPAL CITIES IN THE U. S. A., CANADA AND OTHER COUNTRIES

ROLAGRIPS

THE COUPLING FOR PLAIN END PIPE

the time-saving, cost-cutting coupling that SIMPLIFIES WATER SERVICE PROBLEMS

A little over a year ago, Rolagrip couplings for plain end pipe were introduced to the water service and sprinkler system trade. Rolagrips caught on quickly, and today you find them widely used in sprinkler systems (for cut-ins, feed mains, risers, cross-mains) and in general water service, for setting of meters, valves and branch lines.

The chief reason why Rolagrips have been so readily accepted is that they're so easy to use. In three simple steps, anyone can apply a Rolagrip — without previous experience, without special tools. Maintenance and repair are greatly simplified too. For example, there's no need for large bell holes when you use Rolagrips, since the couplings can quickly be tightened and loosened from above.

Such savings in time and labor naturally produce worthwhile money savings. Try Rolagrips *now* — they're available in sizes 1½" - 12", ready to use with any steel or wrought iron pipe, new or used.

GUSTIN-BACON MANUFACTURING CO.

210 W. 10th ST. KANSAS CITY, MO.

BLOCK THAT FIRE HAZARD WITH

The revolutionary Hooperwood FIRE-CHIEF® process really makes canvas highly fire-resistant. FIRE-CHIEF also makes the canvas resistant to the ravages of water, weather, and mildew. Tensile strength is preserved, and the canvas stays pliable. It lasts *several times* as long as untreated canvas.

FIRE-CHIEF is available in three forms: As finished Hooperwood FIRE-CHIEF Canvas; as protection we apply to the customer's own fabrics; as FIRE-CHIEF Compound to be applied to new or used canvas. Write us today for further information on Hooperwood FIRE-CHIEF Canvas and FIRE-CHIEF processing.

WM. E. HOOPER & SONS CO.

***General Sales Offices:* Juniper and Cherry Sts., Philadelphia 7, Pa.**
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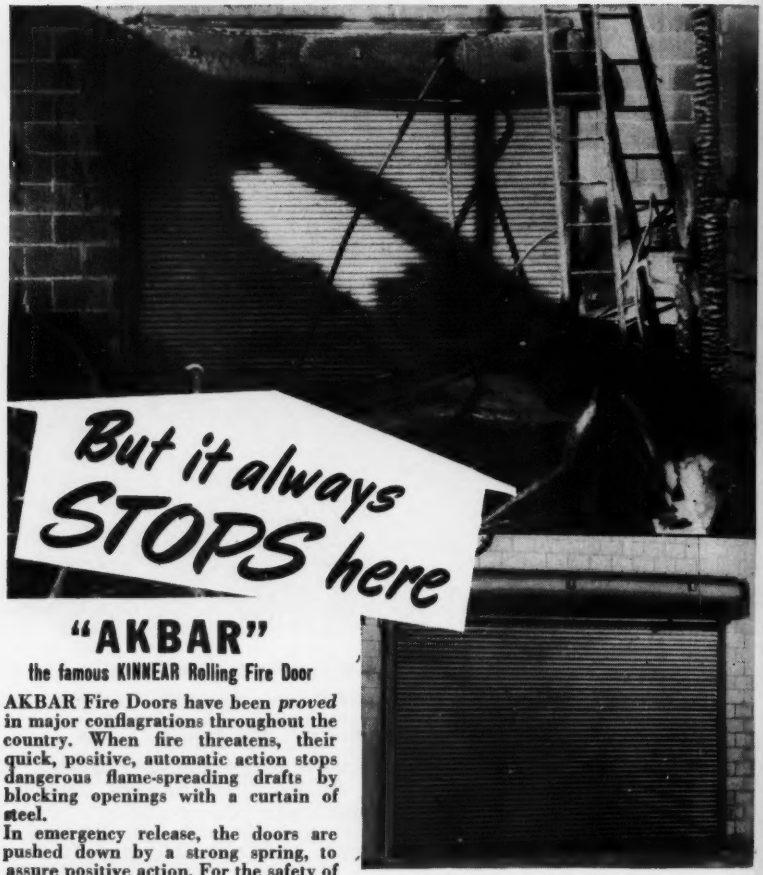
***Hooperwood Mills:* Woodberry, Baltimore 11, Md.**

Fire can START anywhere . . .



"AKBAR"

the famous KINNEAR Rolling Fire Door

AKBAR Fire Doors have been *proved* in major conflagrations throughout the country. When fire threatens, their quick, positive, automatic action stops dangerous flame-spreading drafts by blocking openings with a curtain of steel.

In emergency release, the doors are pushed down by a strong spring, to assure positive action. For the safety of building occupants, downward speed of the doors is regulated. And the doors can be opened after closure, for emergency exit. Another device stops the door at floor level, with the steel curtain covering the entire opening — it will not sag, or drop through a fire-weakened sill.

When not in use, Akbar doors remain coiled overhead, out of the way. Approved by Underwriters' Laboratories, Inc., they can be installed in openings of any size, in old or new buildings. They can be equipped for regular, daily service, with motor operation. However, non-labeled Kinnear Rolling Doors are recommended where maximum fire protection is not required. Write for catalog.

KINNEAR ROLLING DOORS

Engineered for Permanence

The KINNEAR MFG. CO.
2250-70 Fields Avenue, Columbus 16, Ohio
1742 Yosemite Ave., San Francisco 24, Calif.
Offices and Agents in All Principal Cities

Deluge Systems, Wet Pipe Systems, Dry Pipe Systems, Water Spray and Fog Systems, Rate-of-Rise Sprinkler Systems, and Foam and Carbon Dioxide Extinguisher Systems.

For New York's Midtown Bus Terminal—the world's largest—Blaw-Knox engineered, fabricated and installed 22 separate sprinkler systems . . . 14 dry and 8 wet, requiring more than 9,000 heads. The size of this installation is relatively unimportant. Rather, it was that critical hazard presented by hundreds of vehicles with full gas tanks which prompted Port of New York Authority engineers to specify the fire-protection system that goes into action *the instant dangerous temperatures develop.*

Why settle for less? Blaw-Knox engineers will determine from a survey of your property the most economical and effective type of fire-protection system and submit their recommendations and estimate without obligation on your part.

"LITTLE JOEY SPRINKLER"

BLAW-KNOX SPRINKLER DIVISION

OF BLAW-KNOX CONSTRUCTION COMPANY

829 Beaver Ave., N. S., Pittsburgh 12, Pa.

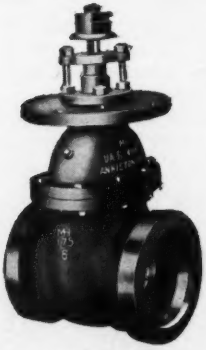
Offices in Principal Cities

M&H PRODUCTS *Everywhere*

M & H Hub End Fire Hydrant

M & H Indicator Post

M & H Tapping Valve and Sleeve



M & H Indicator Post Valve

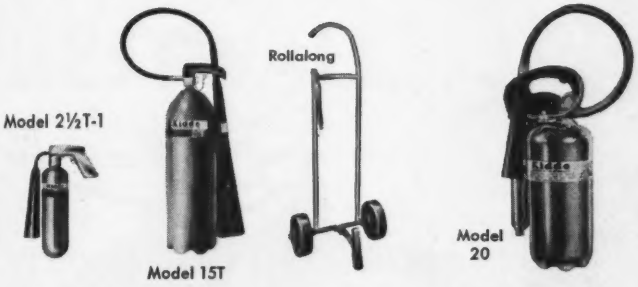
UNDERWRITERS and FACTORY MUTUALS APPROVED and LISTED

Field reports establish the fact that M & H Valves and Fire Hydrants are correctly designed, dependable in operation, with a record of long life and freedom from repair. Engineers recommend M & H Valves and Hydrants on basis of low cost per year of service. Sizes of valves 4 to 14 inch, inclusive with all standard end connections, including Mechanical Joint.

COMPLETE INFORMATION ON REQUEST

M & H VALVE AND FITTINGS COMPANY
ANNISTON, ALABAMA

Kidde Hand Extinguishers Mean Quick Death to Fire!



CARBON DIOXIDE (CO_2) PORTABLES

Kidde Hand Portables are effective in fighting incipient fires in flammable liquids and electrical equipment. CO_2 capacities from 2½ to 25 pounds. All sizes equipped with easy-to-operate Trigger-Finger Control.

The Rollalong is a simple method of transporting larger size extinguishers easily and quickly.

DRY CHEMICAL EXTINGUISHERS

Kidde Dry Chemical Extinguishers are especially effective for fires in flammable liquids and electrical equipment. Like *Kidde* CO_2 Portables, they are equipped with Trigger-Finger Control. Design prevents packing of the dry chemical. Horn construction gives improved discharge pattern. Made in 20 and 30 pound capacities.

WET CHEMICAL STAINLESS STEEL EXTINGUISHERS

Kidde's 2½ Gallon Wet Chemical Stainless Steel Extinguisher gives you greater strength, lighter weight, safer construction and lower price. Your choice of clear water, soda-acid or foam type—with new transparent nozzle and permanent nameplate that can't fall off. Also available—Anti-Freeze type, of silicon bronze to eliminate danger of corrosion.

Kidde

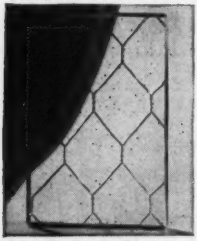
Kidde Extinguishers carry highest rating of Underwriters' Laboratories and The Factory Mutuals

Walter Kidde & Company, Inc., 1051 Main St., Belleville 9, N. J.
Walter Kidde & Company of Canada, Ltd., Montreal, P. Q.

MISSISSIPPI WIRE GLASS

the Approved Fire Safeguard

Polished Misco Wire Glass, highest achievement of the rolled glass manufacturer's art, combines the utmost in protection with modern beauty.



Polished Wire Glass by Mississippi approved fire safeguard, helps prevent drafts . . . is effective in holding fires within bounds of origin.

Records over the years conclusively demonstrate that Mississippi Wire Glass, approved fire retardant No. 32, is a dependable defense against the spread of fire. For over half a century architects and engineers have specified Mississippi Wire Glass . . . the original solid wire glass upon which the Underwriters' Standard was based in 1899 . . . the standard today by which all others are judged. Mississippi Wire Glass affords constant protection at minimum cost in windows, doors, transoms, skylights, fire escapes, vertical shafts, partitions, exterior walls and all other places where fire or breakage protection is required. Carried in stock by distributors of quality glass everywhere.

Where full vision is not required, obscure Mississippi Wire Glass is available with either hexagonal or Misco wire netting.

This Seal Identifies Mississippi Wire Glass

Send For Catalog No. 52
Free Samples on Request.
For details see Sweet's Architectural File

MISSISSIPPI Glass COMPANY
88 ANGELICA ST. SAINT LOUIS 7, MO.
NEW YORK • CHICAGO • FULLERTON, CALIF.
WORLD'S LARGEST MANUFACTURER OF ROLLED, FIGURED AND WIRED GLASS

The greatest improvement ever made
in dry wall construction

FIRESTOP BESTWALL®

An exclusive CERTAIN-TEED development

ALL THE ADVANTAGES OF CONVENTIONAL GYPSUM WALLBOARD—*PLUS UP TO THREE TIMES THE FIRE RESISTANCE*

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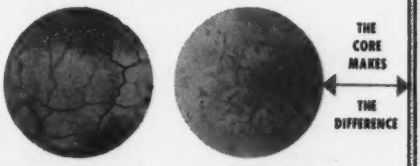

Untouched photo showing a section of ordinary gypsum wallboard after it has been subjected to a fire temperature of 1,700°F. for 1 hour. Note the shrinkage cracks, characteristic of ordinary gypsum exposed to heat.

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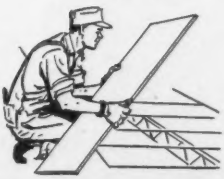

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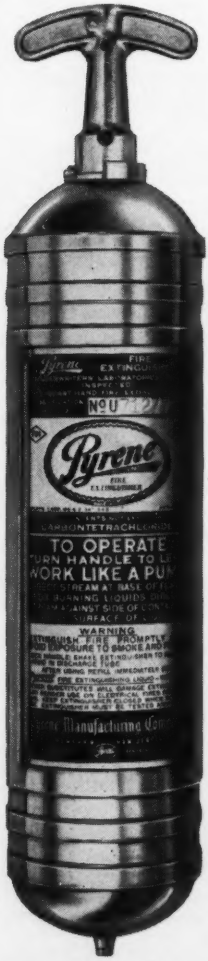

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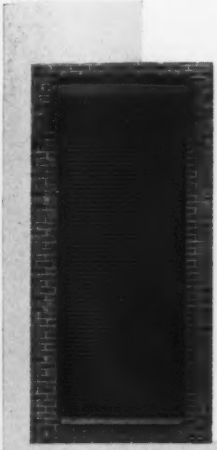
FIRE DOORS *and* WINDOW SHUTTERS
PREVENT SPREAD *of* FIRE!



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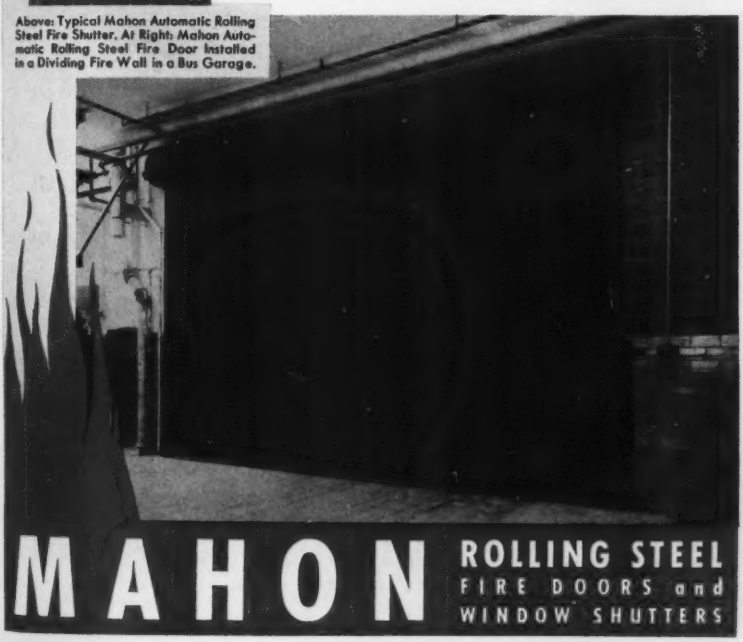
Above: Typical Mahon Automatic Rolling Steel Fire Shutter. At Right: Mahon Automatic Rolling Steel Fire Door Installed in a Dividing Fire Wall in a Bus Garage.



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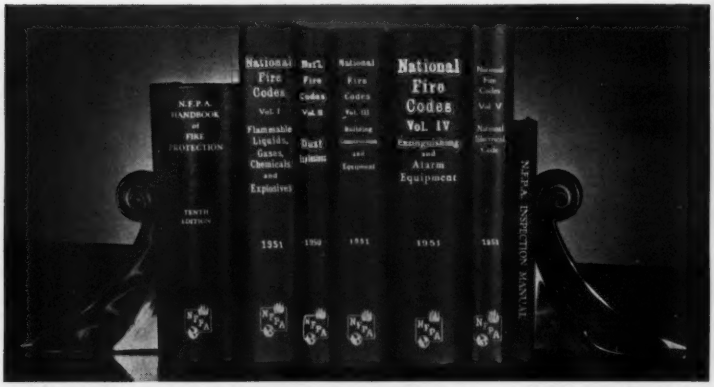
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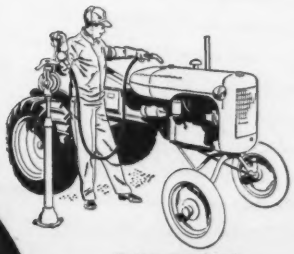

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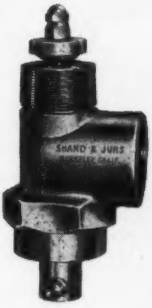
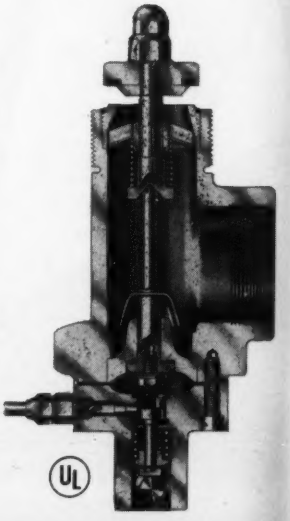


Developed jointly by Phillips Petroleum Company and S&J, "Safetiflo," S&J Fig. 13980, has had over five years extensive field testing. The cast steel body is provided with a weakness groove, and with the two-piece operating stem, permits complete or partial break-off of the valve at the tank outlet without impairing valve closure or reducing safety. If you want to make your LP-Gas deliveries faster and safer, contact the nearest branch office listed below or the S&J factory for additional information on the new "Safetiflo" LP-Gas valve.



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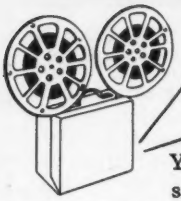

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Fire Safe

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PACKAGED-MASONRY

CHIMNEY

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DOUBLE SEAL JOINTS —ACID PROOF CEMENT AND DRAW BAND
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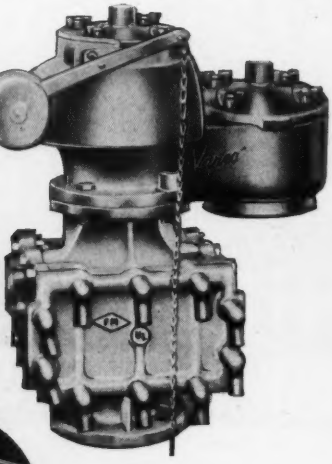
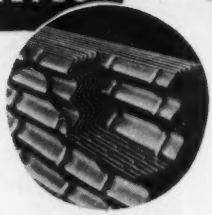
with "Varec" FLAME ARRESTERS In combination with your VENT VALVES





"VAREC" Fig. No. 5800 Vent Unit consisting of "VAREC" Conservation Vent Valve in combination with "VAREC" Flame Arrester.

The belief that conservation vents or breather valves alone will prevent travel of flame back into flammable liquid storage tanks is questionable because of the many contributing factors. Careful authoritative analysis reveals that valves by themselves do provide *some protection* but this "protection" *is by no means adequate* under all circumstances.

Safety authorities emphatically advise that "vent valves are not regarded as providing the required protection against fire and explosion." A textbook on safety states that "a conservative policy is to provide flame arresters in conjunction with other vent equipment on all cone-roof atmospheric tanks handling oils with a flash point up to 200°F open cup."

"VAREC" Flame Arresters when used as a unit with "VAREC" Vent Valves give you full fire protection at extremely low cost. Average installations run approximately .1 of 1% of your investment in tank and products. Consult your nearest "VAREC" representative or write for further information.

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VF-1

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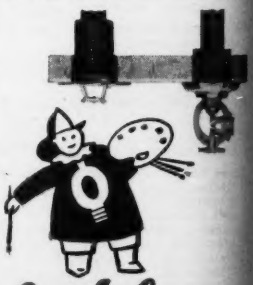
The development of the "Automatic 400" **Ceiling Sprinkler** discounts the adage that you can't have beauty and fire protection too. For here is a sprinkler head that is designed to blend perfectly with the appointments of the most tastefully designed interior—finished in bronze or chrome, bright or satin, it projects less than one inch below the ceiling surface. Yet, regardless of its beauty, it's ready, willing and able to automatically extinguish fire whenever called upon to do so.

You'll find the "Automatic 400" **Ceiling Sprinkler** installed in the most distinctively decorated offices, stores, restaurants and public buildings. No longer is it necessary to sacrifice "eye appeal" in order to have fire protection that offers both safety and savings.



Contact our nearest "Automatic" Sprinkler representative for engineering counsel, surveys and estimates. They are available to you without obligation. Ask for free literature.

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA
YOUNGSTOWN 1, OHIO

"Automatic" Sprinkler

FIRST IN FIRE PROTECTION

DEVELOPMENT . ENGINEERING MANUFACTURE . INSTALLATION

OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

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Municipal Fire Alarm Systems

Until the Fire Department knows there is a fire — and the exact location— it can do nothing about it.

For the protection of the values at risk — human life, property, business and income — adequate fire alarm box distribution is a sound investment.

The Standard Municipal Box

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We also supply complete systems for industrials and institutions. Write for our catalog descriptive of the Vigilarm System of Automatic Fire Detection.

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No Secret Weapons!

Success in the daily battle against fire requires no secret weapons. Grinnell Automatic Sprinklers are known throughout the world as the most dependable and the deadliest weapons to combat this ever-lurking enemy. For more than 70 years they have been on silent guard duty, day and night, to stop fire at its source. Today, millions of lives and billions of dollars in property are entrusted to their sure protection.

There are various types of Grinnell Fire Protection Systems, designed to combat fire in practically any hazard. Complete information on any or all of them is available for the asking from our offices in principal cities. Grinnell Company, Inc., Providence 1, R. I.

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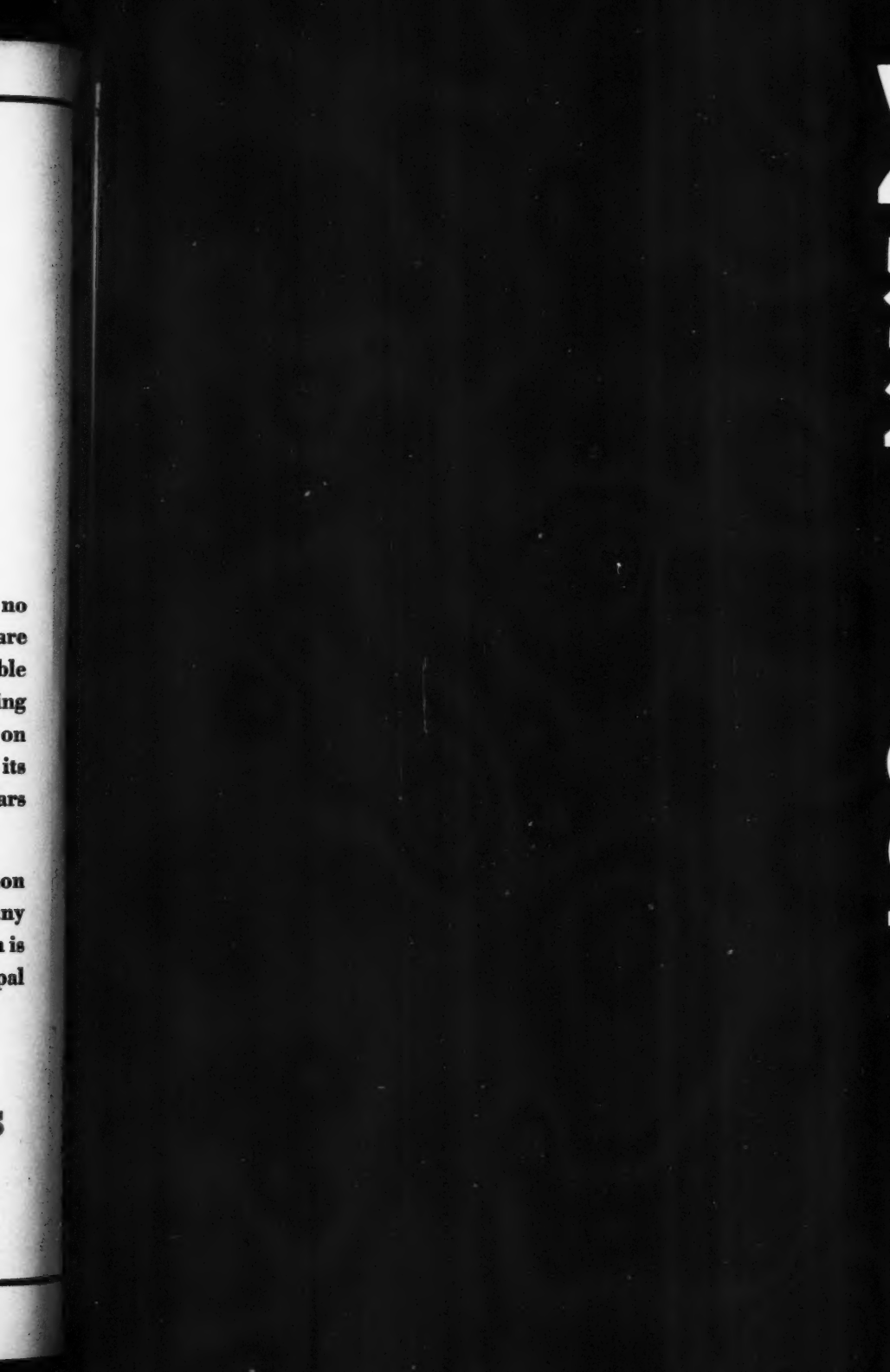
For Protection Against Fire